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WEATHER BUREAU

CHARLES F. MARVIN, Chief

MONTHLY WEATHER REVIEW

VOLUME 44, No. 8

AUGUST, 1916

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NOTICE TO CONTRIBUTORS.

Contributions intended for publication in any given issue of the MONTHLY WEATHER REVIEW (e. g., January) should be in the hands of the Editor before the end of the next following month (e. g., February), if no illustrations are required. When the paper is illustrated, the manuscript and the copy for the illustrations must be submitted much earlier, in order to permit copy being prepared for the engraver by the end of the month.

REPRINTS are made up without covers in the original size and pagination of the REVIEW. They will not be furnished unless specifically REQUESTED WHEN THE MANUSCRIPT IS SUBMITTED.

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INTRODUCTION.

As explained in this Introduction during 1914, the MONTHLY WEATHER REVIEW now takes the place of the Bulletin of the Mount Weather Observatory and of the voluminous publication of the climatological service of the Weather Bureau. The MONTHLY WEATHER REVIEW contains contributions from the research staff of the Weather Bureau and also special contributions of a general character in any branch of meteorology and climatology.

SUPPLEMENTS to the MONTHLY WEATHER REVIEW will be published from time to time.

The climatological service of the Weather Bureau is maintained in all its essential features, but its publications, so far as they relate to purely local conditions, are incorporated in the monthly reports "Climatological Data" for the respective States, Territories, and colonies.

Since August, 1915, the material for the MONTHLY WEATHER REVIEW has been prepared and classified in accordance with the following sections:

SECTION 1.—*Aerology.*—Data and discussions relative to the free atmosphere.

SECTION 2.—*General meteorology.*—Special contributions by any competent student bearing on any branch of meteorology and climatology, theoretical or otherwise.

SECTION 3.—*Forecasts and general conditions of the atmosphere.*

SECTION 4.—*Rivers and floods.*

SECTION 5.—*Seismology.*—Results of observation by Weather Bureau observers and others as reported to the Washington office. Occasional original papers by prominent students of seismological phenomena.

SECTION 6.—*Bibliography.*—Recent additions to the Weather Bureau library; recent papers bearing on meteorology.

SECTION 7.—*Weather of the month.*—Summary of local weather conditions; climatological data from regular Weather Bureau stations; tables of accumulated and excessive precipitation; data furnished by the Canadian Meteorological Service; monthly charts Nos. 1, 2, 3, 4, 5, 6, 7, 8, the same as hitherto; Meteorological Summary and chart No. 9 of the North Atlantic Ocean for this month in 1915. Owing to the fact that ocean meteorological data are frequently not available for a considerable time after the close of the month to which they relate, the chart and text matter in connection therewith appear one year late.

In general, appropriate officials prepare the seven sections above enumerated; but all students of atmospherics are cordially invited to contribute such additional articles as seem to be of value.

The voluminous tables of data and text relative to local climatological conditions, that during recent years were prepared by the 12 respective "district editors," are omitted from the MONTHLY WEATHER REVIEW, but collected and published by States at selected section centers.

The data needed in Section 7 can only be collected and prepared several weeks after the close of the month designated on the title-page; hence the REVIEW as a whole can only issue from the press within about eight weeks from the end of that month.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are especially due to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but such publication is not to be construed as official approval of the views expressed.

CORRIGENDA.

In the REVIEW for July, 1916:
Page 383, col. 2, last line, *for* 7.9 & 2.0, *read* −7.9 and +2.0.
In the REVIEW for June, 1916:
Page 329, col. 2, footnote 1 should be transferred above the table of limiting precipitation, which belongs to the footnote.
In the REVIEW for May, 1916:
Page 281, col. 1, footnote 9, the reference should be
McAdie, A. G. Rainfall of California. Berkeley, Cal., 1914. (Univ. Cal., Public. in geogr., v. 1, no. 4.) pp. 171–173.

SECTION I.—AEROLOGY.

SOLAR AND SKY RADIATION MEASUREMENTS DURING AUGUST, 1916.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated: Washington, D. C., Sept. 30, 1916.]

For a description of instrumental exposures, and an account of the methods of obtaining and reducing the measurements, the reader is referred to the Reviews for January, April, and May, 1916, **44**:2, 179, 180, and 244.

The monthly means and departures from normal values given in Table 1 show that direct solar radiation intensities averaged slightly below normal at all stations except Lincoln, Nebr., the minus departures being most pronounced at Washington, D. C. At the latter station, however, a noon intensity of 1.43 gram-calories per minute per square centimeter, measured on the 14th, exceeds any previous August measurement at Washington by 2 per cent. A noon intensity of 1.42 gram-calories, measured at Lincoln on August 28, is likewise 2 per cent in excess of any August measurement of last year at that station.

Extrapolating to zero air mass, and reducing to mean solar distance of the earth, the radiation measurements obtained at Washington on August 14 give an intensity of 1.66 gram-calories, while those obtained at Santa Fe on August 31 give an intensity of 1.68 gram-calories—a very close agreement when we take into account the vapor-pressure differences shown in Table 2.

TABLE 1.—*Solar radiation intensities during August, 1916.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.
Aug. 8	1.03	0.73	0.51							
14	1.44	1.32	1.23	1.15	1.07	0.99				
17	1.20	0.90	0.69	0.52	0.42	0.35	0.30			
18	1.07	1.00	0.83	0.68	0.63	0.58				
19	1.20	1.03	0.88	0.74						
20	1.18	1.00	0.84	0.73	0.65					
22	1.22	1.05	0.83	0.77	0.67	0.58	0.51			
23		0.84								
24	1.35		0.86	0.76						
25	1.20	0.86	0.70	0.58	0.47	0.38				
26	1.10	0.99	0.87							
28	1.24									
31	1.09	0.92	0.72	0.58	0.50					
Monthly means	1.19	0.97	0.81	0.72	0.63	0.58	(0.40)			
Departure from 8-year normal	−0.03	−0.07	−0.06	−0.07	−0.07	−0.03	−0.03			
P. M.										
Aug. 14		1.31	1.21	1.11						
22		0.98	0.85	0.74	0.65	0.57				
24		1.15	0.98	0.83	0.69	0.57	0.49	0.41		
25		0.92	0.79	0.70	0.63	0.56	0.51	0.45	0.40	0.34
31		0.82		0.55						
Monthly means		1.04	0.96	0.79	0.66	0.57	0.50	(0.43)	(0.40)	(0.34)
Departure from 8-year normal		−0.03	+0.01	−0.01	−0.02					

TABLE 1.—*Solar radiation intensities during August, 1916*—Continued.

[Gram-calories per minute per square centimeter of normal surface.]

Madison, Wis.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.
Aug. 8	1.19	1.05	0.92	0.81						
9		1.07	0.89							
11	1.31	1.21	1.11							
12		1.10	0.93	0.89	0.84					
16	1.24	1.07		0.83						
18	1.13	1.08	1.01	0.91	0.83					
23	1.36	1.22	1.11	1.02						
24	1.32	1.25	1.18	1.08	0.99	0.92	0.88	0.81		
25	1.39	1.27								
28		1.30	1.20	1.12	1.05	0.98				
29	1.34	1.21								
30		1.20	1.05	0.93	0.83					
Monthly means	1.28	1.17	1.04	0.95	0.91	(0.95)	(0.88)	(0.81)		
Departure from 7-year normal	−0.02	−0.01	−0.04	−0.06	+0.01	−0.09	+0.02	+0.03		
P. M.										
Aug. 18		1.09								
24			1.09							
25		1.28								
29		1.15	1.00	0.92	0.80					
30		1.08	0.95	0.85						
Monthly means		1.15	1.01	(0.88)	(0.80)					
Departure from 7-year normal		+0.02	+0.01	+0.01	+0.04					

Lincoln, Nebr.

A. M.										
Aug. 2		1.11								
3	1.23									
4		1.18	1.05	0.96	0.88	0.81	0.74			
12		1.12	1.06	0.94	0.84	0.77	0.72	0.69		
17		1.19	1.06	0.96	0.87	0.78				
18	1.33	1.23	1.10	1.03	0.91	0.85	0.73	0.68	0.66	
19	1.36	1.22	1.13	1.04						
23	1.39	1.23	1.12	1.00	0.89	0.81				
24	1.40	1.29	1.20	1.13	1.07	0.99	0.86	0.79	0.76	0.73
25				1.22	1.08	1.02	0.89			
28	1.46	1.35	1.25	1.18	1.11	1.05	0.99	0.93	0.90	0.87
29	1.31	1.21	1.12	1.03	0.95					
Monthly means	1.35	1.21	1.12	1.05	0.96	0.88	0.82	0.77	0.77	(0.80)
Departure from 2-year normal	+0.05	+0.06	+0.08	+0.08	+0.10	+0.09	+0.08	+0.11	+0.08	
P. M.										
Aug. 2		1.18	1.08	0.99	0.92	0.84	0.78			
3		1.13		0.91	0.83	0.76	0.68			
8			1.10	1.01	0.90	0.80	0.75			
10		1.12	1.04		0.83	0.79	0.74			
11			1.12	1.02	0.94	0.87	0.79			
12			0.86							
15			1.00	0.88	0.80	0.71	0.64			
17		1.15	1.02	0.90	0.83	0.76	0.69	0.63	0.58	
18		1.20	1.06	0.97	0.89	0.82	0.75	0.70	0.67	
19		1.16								
21		1.26	1.14	1.05	0.98	0.92	0.85	0.80	0.74	0.68
22			1.23	1.12	1.05	0.96	0.87	0.83	0.80	0.78
28		1.38	1.29	1.19	1.11	1.03	0.95	0.89	0.83	
Monthly means		1.20	1.09	1.00	0.92	0.84	0.77	0.77	0.72	0.73
Departure from 2-year normal		+0.03	+0.01	+0.01	+0.02	+0.01	+0.03	+0.05	+0.02	+0.03

TABLE 1.—*Solar radiation intensities during August, 1916*—Continued.

[Gram-calories per minute per square centimeter of normal surface.]

Santa Fe, N. Mex.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.
Aug. 1	.....	1.35	1.23	1.19	1.16	1.11	.....	.....	.....	.....
7	.....	.....	1.07	1.00	0.93	0.87	.....	.....	.....	.....
9	.....	1.14	1.04	0.98	0.92	0.85	0.80	0.75	.....	.....
26	.....	.....	.....	.....	1.18	1.13	1.07	1.05	1.01	.....
28	1.44	1.30	1.24	1.20	1.15	.....	.....	1.03	1.00	.....
29	1.35	1.28	1.20	1.13	1.07	1.01	0.96	0.91	0.87	0.83
31	.....	1.40	1.33	1.26	1.19	1.13	1.08	1.04	1.00	0.97
Monthly means	(1.40)	1.29	1.18	1.13	1.09	1.02	0.98	0.96	0.97	(0.90)
Departure from 4-year normal	−0.03	−0.03	−0.04	−0.02	−0.01	−0.02	.....	.....	.....	.....

Sky-light polarization measurements made at Washington on nine days, with the sun at zenith distance 60°, give a mean of 50 per cent, and a maximum of 66 per cent on the 14th. This latter is only 1 per cent lower than the highest August polarization measurement ever obtained at Washington.

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Dates.	8 a. m.	8 p.m.	Dates.	8 a.m.	8 p.m.	Dates.	8 a.m.	8 p.m.	Dates.	8 a.m.	8 p.m.
1916.	Mm.	Mm.	1916.	Mm.	Mm.	1916.	Mm.	Mm.	1916.	Mm.	Mm.
Aug. 8	19.89	20.57	Aug. 8	15.11	14.10	Aug. 2	17.96	18.59	Aug. 1	9.14	9.83
14	9.14	13.13	9	13.13	13.61	3	16.20	16.79	7	8.81	10.59
17	14.60	18.59	11	13.61	13.13	4	17.37	17.96	9	9.14	7.87
18	14.10	16.20	12	11.81	12.24	8	12.68	13.13	26	7.29	7.87
19	14.60	16.20	16	14.10	14.60	10	17.37	17.96	28	6.76	5.79
20	15.11	17.57	18	20.57	17.37	11	12.24	14.10	29	8.48	9.83
22	18.59	23.60	23	10.21	8.81	12	13.61	17.37	31	8.48	7.29
23	17.37	16.20	24	10.21	10.21	15	17.37	18.59			
24	11.81	13.61	25	8.48	8.81	17	18.59	19.23			
25	13.61	14.10	28	7.87	7.04	18	15.11	16.20			
26	16.20	17.37	29	8.48	9.14	19	15.11	16.79			
28	16.79	10.97	30	9.83	13.13	21	14.60	15.11			
31	14.10	16.20				22	10.59	10.59			
						23	9.14	11.81			
						24	10.59	11.38			
						25	10.59	10.97			
						28	8.18	7.04			
						29	7.04	11.38			

Table 3 shows a deficiency of radiation at Washington during the first half of August, which was more than made up by the excess during the second half. At Madison there was an excess of radiation for the month amounting to 7.8 per cent of the average August total. At Lincoln there was a deficiency of radiation during the second decade, but the departures from the normal were slight during the first and third decades.

TABLE 3.—*Daily totals and departures of solar and sky radiation during August, 1916.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.
1	491	363	305	−1	−115	−215	−1	−115	−215
2	616	547	618	126	72	101	125	−43	−114
3	375	312	625	−113	−161	110	12	−204	−4
4	349	294	612	−137	−177	100	−125	−381	96
5	402	388	580	−82	−81	70	−207	−462	166
6	368	565	472	−113	99	−35	−320	−363	131
7	528	594	331	49	130	−174	−271	−233	−43
8	535	600	609	59	139	107	−212	−94	64
9	371	606	458	−103	148	−42	−315	54	22
10	502	212	517	31	−243	20	−284	−189	42
11	236	521	257	−233	69	−238	−517	−120	−196
12	477	446	509	11	−3	17	−506	−123	−179
13	332	648	208	−131	202	−281	−637	79	−460
14	668	349	132	207	−94	−355	−430	−15	−815
15	406	227	494	−52	−213	10	−482	−228	−805
16	125	541	359	−330	104	−123	−812	−124	−928
17	550	479	604	98	44	125	−714	−80	−803
18	529	563	610	79	131	134	−635	51	−669
19	562	478	603	115	49	129	−520	100	−540
20	556	531	477	111	105	6	−409	205	−534
Decade departure							−125	+394	−576
21	461	505	560	19	82	92	−390	287	−442
22	535	259	458	95	−161	−7	−295	126	−449
23	313	560	526	−124	143	63	−419	269	−386
24	576	550	568	141	136	108	−278	405	−278
25	521	551	438	89	140	−19	−189	545	−297
26	527	430	311	97	22	−144	−92	567	−441
27	469	592	613	42	186	160	−50	753	−281
28	445	567	599	20	164	148	−30	917	−133
29	420	543	533	−3	143	84	−33	1,060	− 49
30	430	514	213	10	116	−234	−23	1,176	−283
31	474	281	132	56	−114	−313	33	1,062	−596
Decade departure							+442	+857	−62
Excess or deficiency since first of year	gr.-cal.						−6,454	+2,705	
	per cent.						−6.7	+2.8	

HIGH HAZE OVER THE SOUTHWESTERN UNITED STATES DURING JULY TO SEPTEMBER, 1916.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated Weather Bureau, Washington, Oct. 2, 1916.]

The following is extracted from a communication by Mr. Ford A. Carpenter, in charge of the Weather Bureau office at Los Angeles, Cal., under date of September 7, 1916:

During the month of July, and especially during the latter part, red sunsets were common; but during the first decade of August both sunrises and sunsets were unusually brilliant. A note in the Daily Local Record describes a typical sunset as follows:

"*August 4, 1916.* Cloudy sunset. The sun set behind cirro-stratus clouds, which formed a low bank on the western horizon. As the sun set the western sky became lit with a yellow glow, which changed to orange, and finally to red."

A description is also given of brilliant sunrise and sunset colors that were observed from the top of Mount Wilson, Cal., on September 3 and 4, 1916, and Mr. C. G. Abbot of the Astrophysical Observatory of the Smithsonian Institution, who was then on Mount Wilson, is quoted as saying—

The presence of dust, probably volcanic, and which was responsible for the vivid colors of sunrise and sunset, greatly interfered with solar radiation work.

Mr. Carpenter further states that between July 28 and August 4, 1916, while on Mount Rainier, Wash., he observed each of the eight sunrises and sunsets, and there was a total absence of other than the usual twilight colors. He therefore infers that the dust cloud did not extend to this high latitude (47° N.).

In a letter of September 20 he forwards a note from Prof. A. E. Douglass, University of Arizona, relative to radiating shadows observed at that place on the underside of the dust layer. It appears that these shadows are first seen 16 minutes after sunset, and continue about 10 minutes, and were best observed on September 14 and 15. Prof. Douglass identifies them as shadows from mountain peaks or clouds in the range running south from San Diego, and about 300 miles from Tuscon in an air line. From the angular height of the shadows he computes the dust layer to be from 12 to 15 miles above the surface.

It does not seem possible to connect this dust or haze with the haze that produced the brilliant twilight colors that were generally observed in the vicinity of Washington, D. C., at the end of July, and also at Lincoln, Nebr., at about the same time.[1] The pyrheliometric observations obtained at Santa Fe, New Mex., Lincoln, Nebr., Madison, Wis., and Washington, D. C., and summarized on another page, give no indications of unusual haze during August. Up to the date of writing this note the Weather Bureau has been unable to learn of a recent volcanic eruption of sufficient violence to cause a haziness of the upper atmosphere of the character observed. We shall be glad to receive further information relative to this interesting phenomenon.

The following is the substance of an additional note from Mr. Carpenter, under date of October 7, 1916:

It is reported from the Lick Observatory, Mount Hamilton, Cal., that red sunsets have been observed since the first week in August. On many nights in August and September the sky was rather thick, and the Milky Way did not stand out as prominently as usual. This and the red sunsets have been interpreted by the observatory to mean that the atmosphere has contained an abnormal amount of finely divided dust.

Red twilight glows have also been reported from San Bernardino and San Diego, Cal., and Phoenix, Ariz. At Tucson, Ariz., no red sunsets have been observed since the middle of September, but here at Los Angeles, in spite of unusually heavy rains during the first few days of October, they do not appear to have decreased in frequency. Whenever the mornings and evenings have been clear the sky has been suffused with a red glow.

In Switzerland.—Added significance is given the above observations by the following note quoted from the British Meteorological Office circular.[2]

Dr. Maurer, director of the Swiss Meteorological Institute, writes from Zurich that since the middle of July the atmosphere in the high Alps has shown noteworthy *optical deterioration*, indicated by the extension of the aureole round the sun, to as much as 140° in diameter at the end of August, and by a true brown Bishop's ring, visible on August 3 and 4. The cause of the deterioration is still in doubt. Corresponding phenomena in 1883–4, 1902–3, and 1912 were attributed to violent volcanic eruptions, but no reports of volcanic eruptions have come to hand this year. Whether or not the cumulative effect of gunfire in the course of two years is equivalent to that of a volcanic eruption there are no figures to show.

[1] *See* MONTHLY WEATHER REVIEW, July, 1916, 44:382. After the publication of the July REVIEW several correspondents in Virginia also reported brilliant sunsets at the end of July.—*H. H. K.*

[2] *Great Britain. Meteorological Office.* Meteorological Office circular No. 4 [London], Sept. 21, 1916. p. 4.

ATMOSPHERIC REFRACTION AT MOUNT HAMILTON, CAL.[1]

Aside from conditions which actually conceal objects or make the images so unsteady that accurate observation is impossible, the atmosphere is of importance to astronomy and geodesy because of its refractive power. Professor Simon Newcomb [2] writes as follows concerning atmospheric refraction:

The refraction of a ray of light by the atmosphere as it passes from a heavenly body to an observer on the earth's surface, is called "astronomical [refraction]." A knowledge of its amount is a necessary datum in the exact determination of the direction of the body. In its investigation the fundamental hypothesis is that the strata of the air are in equiliorium, which implies that the surfaces of equal density are horizontal. But this condition is being continually disturbed by aerial currents, which produce continual slight fluctuations in the actual refraction, and commonly give to the image of a star a tremulous motion. Except for this slight motion the refraction is always in the vertical direction; that is, the actual zenith distance of the star is always greater than its apparent distance. The refracting power of the air is nearly proportional to its density. Consequently the amount of the refraction varies with the temperature and barometric pressure, being greater the higher the barometer and the lower the temperature.

At moderate zenith distances, the amount of the refraction varies nearly as the tangent of the zenith distance. Under ordinary conditions of pressure and temperature it is, near the zenith, about one second [of arc] for each degree of zenith distance. As the tangent increases at a greater rate than the angle, the increase of the refraction soon exceeds one second for each degree. At 45° from the zenith the tangent is 1 and the mean refraction is about 58 seconds. As the horizon is approached the tangent increases more and more rapidly, becoming infinite at the horizon; but the refraction now increases at a less rate, and, when the observed ray is horizontal, or when the object appears on the horizon, the refraction is about 34 minutes, or a little greater than the diameter of the sun or moon. It follows that when either of these objects is seen on the horizon their actual direction is entirely below it. One result is that the length of the day is increased by refraction to the extent of about five minutes in low latitudes, and still more in higher latitudes. At 60° the increase is about nine minutes.

The atmosphere, like every other transparent substance, refracts the blue rays of the spectrum more than the red; consequently, when the image of a star near the horizon is observed with a telescope, it presents somewhat the appearance of a spectrum. The edge which is really highest, but seems lowest in the telescope, is blue, and the opposite one red. When the atmosphere is steady this atmospheric spectrum is very marked and renders an exact observation of the star difficult.

Again writing of the difficulties connected with this study, he says: [3]

There is perhaps no branch of practical astronomy on which so much has been written as on . . . [refraction] and which is still in so unsatisfactory a state. The difficulties connected with it are both theoretical and practical. The theoretical difficulties . . . arise from the uncertainty and variability of the law of diminution of the density of the atmosphere with height and also from the mathematical difficulty of integrating the equations of the refraction for altitudes near the horizon after the best law of diminution has been adopted.

In spite of the difficulties, however, all accurate position work demands that the observed positions of stars be corrected for atmospheric refraction. This necessity has led to the construction of "refraction tables" from which a correction for atmospheric refraction can

[1] *Comstock, G. C.* Reduction tables for the Lick Observatory III, IV, and V (1883) Univ. Cal. publ. Lick observ., 1:221-258 (Sacramento, Supt. State Printing, 1887).

Tucker, R. H. The refraction, *in* Meridian circle observations made at the Lick Observatory 1896-1901. Univ. Cal. publ. Lick observ., 6:150-155. (Sacramento, Supt. State Printing, 1903.)

Tucker, R. H. The refraction, *in* Meridian circle observations made at the Lick Observatory 1901-1906. Univ. Cal. publ. Lick observ., 10:14-17. (Sacramento Supt. State Printing, 1907.)

Crawford, R. T. On astronomical refraction. Univ. Cal. publ. Lick observ., 7 [1902-1911]: (part 6) 159-216, [1909]. (Sacramento, Supt. State Printing, 1913.)

Tucker, R. H. Diurnal variation in the refraction at Mt. Hamilton. Univ. Cal. publ. astron., Berkeley, 1913, 7:130-139. (Lick Observ. bul. 231.)

Tucker, R. H. The diurnal variation of the refraction. Astron. soc. Pacific publ., San Francisco, 1916, 28:69-73.

Recent observations on the diurnal change in the refraction at Lick observatory. Ibid., 28:199-200.

[2] *N[ewcomb], S.* Astronomical refraction. Encyc. Britannica, ed. 11, New York, 1911. 23:29.

[3] *Newcomb, S.* A compendium of spherical astronomy. New York, 1906, p. 223.

In this connection, especially for the Pacific coast mountains of the United States, see *Schott, C. A.* "Hourly values of the coefficient of refraction," *in* The transcontinental triangulation and the American arc of the parallel, Washington, 1904, p. 254-256. (U. S. Coast and Geodetic Survey, Special publ. No. 4.)

be obtained for a star at any apparent zenith distance.[4] In all cases it is necessary to assume that refraction introduces no errors of azimuth, although this is sometimes far from the truth.[5]

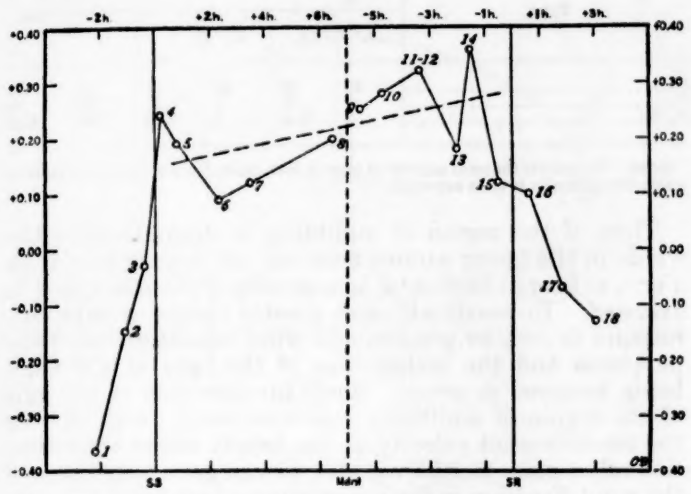

FIG. 1.—Corrections to the Pulkova refractions, for the Lick Observatory. SS = sunset; SR = sunrise. (After R. H. Tucker.)

Note the sudden fall in correction about 2 hours *after* SS, and again about 2 hours *before* SR.

Refined work at Lick Observatory and elsewhere has shown not only that the correction for refraction determined by the Pulkova tables is often too large but also that there is a diurnal variation in the refraction.[6] Figure 1[7] shows the march of the variation in refraction at Mount Hamilton based on observations during the years 1905 and 1906. The average variation is plotted with reference to the time of sunrise and sunset.

Partly because of the unsatisfactory condition of the refraction correction from both theoretical and practical considerations and in part because it was recognized that every observatory—particularly one situated at a considerable altitude—might present a special case requiring individual treatment, every observation of a standard star made at Lick Observatory has been so handled that the derived value of the latitude presents a contribution to the refraction correction. It has been shown from theoretical considerations that the standard Pulkova equations are applicable for atmospheric pressures as low as 850 millibars (25 inches).[8]

Refraction anomalies related to sunrise and sunset.

The study of the refraction data when the anomalies were arranged by hours showed comparatively little system, although a seasonal influence was manifest. The data did show, however, a slight progressive change during the night. Much more system appeared in the anomalies when the data were arranged with reference to sunrise and sunset. There is a very rapid change within two hours of each of these two epochs. Mr. Tucker[9] finds that the effect may be considered due to the action of the sun while above the horizon in changing the atmospheric refraction from that computed for temperatures based upon thermometers exposed at the surface of the earth. The actual recorded temperatures and their changes up or down during the hours of observation had no direct influence on the general result.

That the differences are not the result of incorrect determination of air temperature has been shown by Crawford's careful study[10] of the temperatures in various parts of the observing room and of the air outside. The construction of the meridian-circle house is such that it is practically a large instrument shelter and all the temperature differences were found to be insignificant.[11]

As the greater part of all meridian work is done at night the discussion of daytime refractions is important only for fundamental work which must be carried through the 24 hours. The attempt has been made to eliminate all errors other than those due to the refraction correction. For south stars errors in the adopted standard declinations were eliminated by differential comparison. It is theoretically possible to eliminate errors in the assumed declinations of circumpolar stars by observing both culminations; but practically the two determinations are made under varying conditions, different nadir readings, different graduation errors, and widely different zenith distances. The course adopted, the only safe one, was to arrange the reduction of the observations in such a manner as to eliminate every error except accidental errors of observation, and these were diminished by the large number of observations reduced.

Besides the difficulty of making daytime observations at all, the accidental errors of such observations are much larger than those of night observations, which are made under much more favorable conditions. The south stars are so much more difficult to see because of their rapid motion and the increased atmospheric glare, that second-magnitude stars, even at moderate zenith distances, are impossible while north stars of similar brightness and altitude present comparatively little difficulty. Tucker finds that "In general from experience at three other important observing stations,[12] the daytime conditions at Mount Hamilton can be described as the worst of all the stations, while night conditions are often the best experienced at any of them."[13]

An effect of the refraction at Mount Hamilton noticed generally in daytime, and as yet unexplained, is that south stars are more steady than north stars when the wind is southerly and north stars are generally more steady when the wind is northerly.

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[4] *Bessel's Tables* (*Friedrich Wilhelm Bessel*):
Fundamenta astronomiæ. Regiomonti. In commissis apud Frid. Nicolovium 1818. Pp. 26–62.
Tabulæ Regiomontanæ reductionum observationum astronomicarum ab anno 1750 usque ad annum 1850 computatæ. Table 14. Regiomonti, Prussorum, 1830.
Pulkova Refraction Tables:
Tabulæ refractionem in usum Speculæ Pulcovensis congestæ Petropoli, 1870.
Tables de refraction de l'Observatoire de Poulkova. St. Petersbourg, 1905.
U. S. Naval Observatory Refraction Tables:
Refraction Tables (Bessel). Washington, April, 1887.
Refraction tables (Pulkova). U. S. Naval Obser. Publ., Ser. 2, Washington, 1904. 4:E30–E54. (Appendix 2).
Reduction tables for Equatorial Observations by C. W. Frederick. U. S. Naval Obser. Publ. 4:F1–F101 (Appendix 3). Washington, 1905.
Lick Observatory Refraction Tables:
Reduction Tables, Comstock, 1883. Univ. Calif. publ. Lick Observ. 1:221–258, Sacramento, Supt. State Printing, 1887.
Refraction Tables, Crawford (1907). Univ. Calif. publ. Lick Observ. 7:201–216. Sacramento, Supt. State Printing, 1913.
de Ball's Tables (L. de Ball):
Refraktionstafeln. Leipzig, Wilh. Engelmann, 1906. xiv, 18 p.

[5] *Campbell, W. W.* Elements of practical astronomy. 2d ed. New York, 1906. p. 33.

[6] See *Newcomb, S.*: Researches on the motion of the moon, Pt. 2, p. 14. U. S. Naval Observ. American Ephemeris and Nautical Almanac. Astron. Papers 9, pt. 1, Washington Govt. Printing Office, 1912.

[7] Univ. Cal. Publ. astron., Berkeley, April 25, 1913, 7, pt. 6 p. 132 (Lick observ., Bul. 231).

[8] *Comstock, G. C.* Reduction tables for the Lick observatory (1883). Univ. Cal., publ. Lick observ., Sacramento, 1887, 1: 223–225. 1887.

[9] *Tucker, R. H.* The diurnal variation of the refraction. Astron. soc. Pacific publ., San Francisco. April, 1916, 28:72.

[10] *Crawford, R. T.* On astronomical refraction. Univ. Cal. publ. Lick observ., Sacramento, 1913. 7 [1902–1911]: (pt. 6) 164–165 [1909].

[11] *Reed, W. G.* Meteorology at the Lick observatory, MONTHLY WEATHER REV., June, 1914, 42: 339–345.

[12] Dudley Observatory, Albany, N. Y., 1879–1883; Argentine National Observatory, Cordoba, Argentina, 1884–1893; Southern Observatory, Carnegie Institution, San Luis, Argentina, 1908–1911.

[13] See above, footnote 9, op. cit., p. 73.

This discussion of sources of error due to real changes in refraction—the effect of which can be determined and accounted for—is of more importance from a meteorological and, probably, even from an astronomical point of view than the many discussions in present-day astronomical literature regarding the failure of methods of observation due to accidental refraction errors, to sluggish levels, and to various instrumental errors. It is, therefore, wholly appropriate that it comes from an observatory whose first director[14] was moved to write:

> The observatory is not primarily designed for a meteorological station. Its very exceptional situation, however, creates a responsibility on its part to engage to some extent in making * * * meteorological observation * * *. The elevated and isolated site of the observatory will render researches on astronomical refraction of especial value, and the disposition of buildings and instruments has been made with this end in view.—*Wm. G. Reed.*

ON THE ABNORMAL PROPAGATION OF SOUND WAVES IN THE ATMOSPHERE.[1]

By S. FUJIWHARA.

[Abstracted for the REVIEW, by *H. Bateman*, Ph. D., Govans, Md.]

1. Shape of the region of audibility.

Peculiarities in the shape of the region of audibility of the sound from an explosion have been noticed very frequently during the last few years and have been associated with various meteorological conditions. The present war has provided splendid opportunities for the study of the propagation of sound waves produced by cannonading, and several papers have been written on the subject. In Japan the frequent explosions and eruptions of Mount Asama have provided even better opportunities for investigation and Japanese scientists have collected some very valuable information and made systematic observations. The material thus obtained has been studied mathematically by S. Fujiwhara in two able memoirs in which he shows that important information with regard to the structure of the atmosphere can be derived from a knowledge of the shape of the region of audibility. Some interesting types of regions are shown in figures 1 to 6.

A brief account of Fujiwhara's first memoir has already been given in this REVIEW (May, 1914, **42:** 258–265). In his second memoir the author uses his mathematical results to obtain an idea of the shape of the region of audibility for each of the five types of atmospheric structure described by C. J. P. Cave in his book The Structure of the Atmosphere in Clear Weather. These are:

(*a*) "Solid" current, in which the wind remains steady in both direction and velocity in the upper layers.

(*b*) Continued increase of velocity beyond that of the gradient wind.

(*c*) Decrease of velocity in the upper atmosphere.

(*d*) Reversal or a great change of direction in the upper layers.

(*e*) An upper wind blowing out from a distant low-pressure center; frequent reversal in the lower layers.

For all the cases in each class Fujiwhara has examined whether a discontinuity of the region of audibility of an explosion can occur or not; his results are shown in Table 1.

TABLE 1.—*Classification of the regions of audibility about an explosion center for the different cases of atmospheric structure described by Mr. Cave.*

Type.	Number of cases.					Total.
	a.	*b.*	*c.*	*d.*	*e.*	
N_t	30	48	27	34	36	175
N_d	0	21	0	20	23	64
N_d/N_t	0	0.44	0	0.59	0.64	0.37

NOTE.—N_t denotes the total number of cases in each class; N_d, the number of cases in which discontinuity is to be expected.

Thus, if the region of audibility is discontinuous the winds in the upper atmosphere can not belong to classes *a* or *c*, *so long as horizontal homogeneity of the atmosphere is assumed.* In nearly all cases greater ranges of rays correspond to smaller gradients of wind velocities—air temperatures and the inclinations of the rays at the start being assumed as given. Since the direction of the axis of the region of audibility coincides nearly with that of the relative wind velocity at the height where the reflection takes place (see §3, eq. (3)), we can get a rough idea of the wind direction in the upper atmosphere from a knowledge of the surface wind and the direction and range of the regions of audibility.

In the first memoir the author pointed out that the occurrence of the detached region of audibility, i. e., an abnormal region, was closely connected with the existence of powerful cyclones. Many cases given in the present paper, however, are not in keeping with the above conclusion. The cases given in the first paper, however, occurred chiefly under weather conditions of the winter type. Now in winter the direction of the monsoon in Japan is northwesterly and no local depression of importance occurs over central Japan. Thus the region of audibility must continuously extend toward the east or southeast under the normal condition of winter. But when a powerful cyclone approaches, the above condition is disturbed, and detached regions of audibility may be detected. In the summer months the direction of the monsoon is southeasterly, and the development and passage of a local depression over central Japan is a daily phenomenon. The direction of the upper wind due to this depression, whose height above sealevel is comparatively small, about the same as that of Mt. Asama, can by no means coincide with that of the monsoon, and hence detached regions of audibility may occur. When a powerful cyclone approaches from the west, we may have abnormal cases in which no detached region can be detected or in which one is found in a direction other than westerly. In the period of transition from the weather of winter to that of summer, or vice versa, the direction of the wind of monsoon type is not confined to the northwest or the southeast, but can be anywhere between the northwest and southeast on the north side. In these periods the energy of the monsoon becomes less and the effect of cyclones or other meteorological elements on the phenomenon of the propagation of sound waves can easily become predominant.

The mathematical theory is worked out on the assumption that the atmosphere is uniform in each horizontal plane. There must also be further abnormalities of propagation when the uniformity is broken by the presence of floating sheets or masses of cloud in which the temperature may be different from that of the surrounding air and when a Helmholtzian wave exists at the boundary of two layers of the atmosphere with different velocities

[14] [*Holden, E. S.*]: Description of the meteorological instruments. Univ. Calif. publ. Lick observ., 1:78 Sacramento, Supt. State Printing. 1887.

[1] *Fujiwhara, S.* On the abnormal propagation of sound waves in the atmosphere. Second part. Bull., Central met'l. obs'y. Tokyo, Japan, 1916, 2, pt. 4. pl., 82 p. 27 lith. 4°.

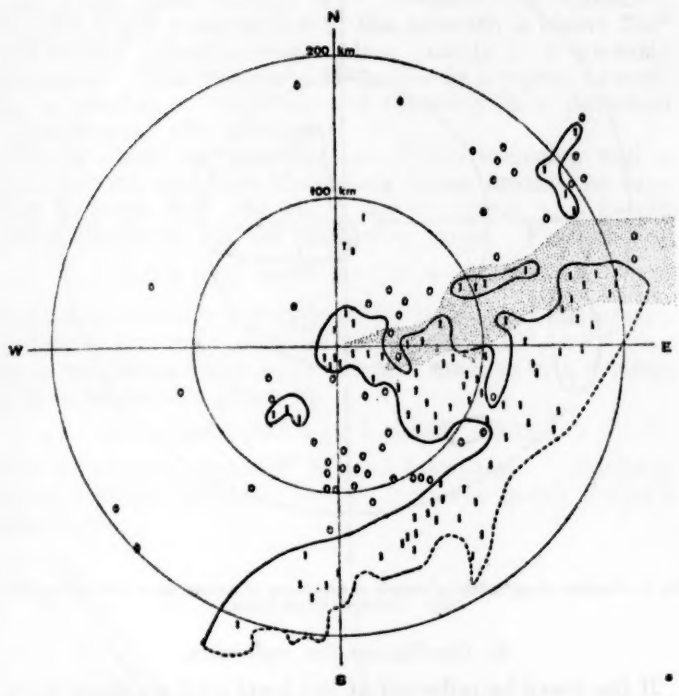

FIG. 1.—Regions of audibility of sounds of explosion of Asama volcano, Dec. 14, 1912. (Number of reports heard indicated by figure at each station.) Ashes fell over the stippled area. (Author's Chart Ia.)

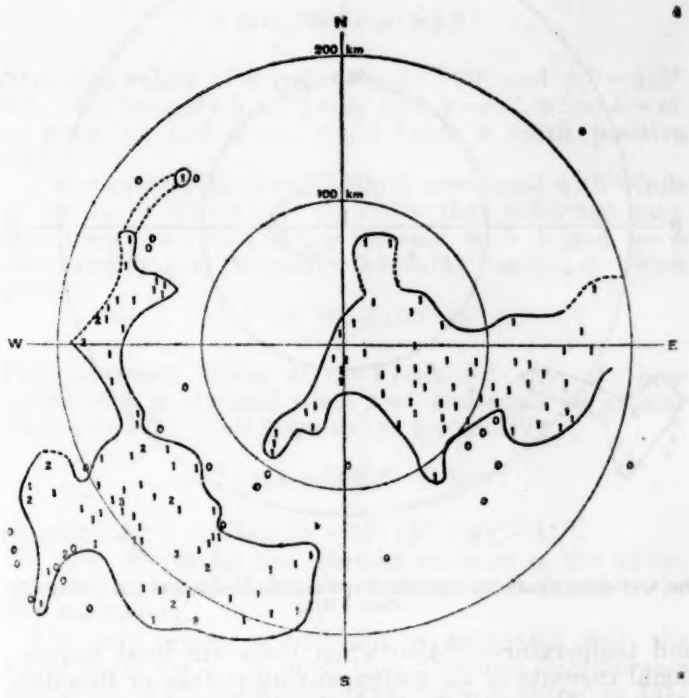

FIG. 2.—Regions of audibility of sounds of explosions of Asama, June 17, 1913. (Author's Chart VIa.)

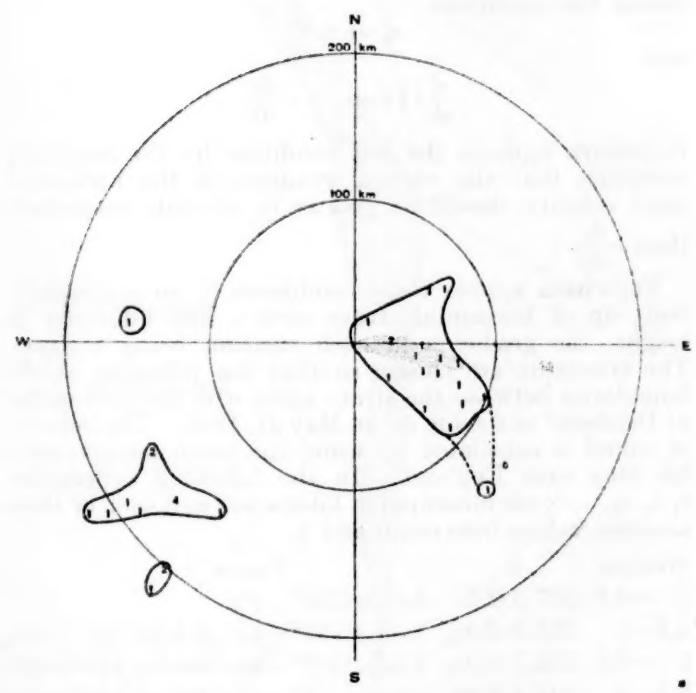

FIG. 3.—Regions of audibility of sounds of explosions of Asama, Aug. 12, 1913. (Author's Chart XIVa.)

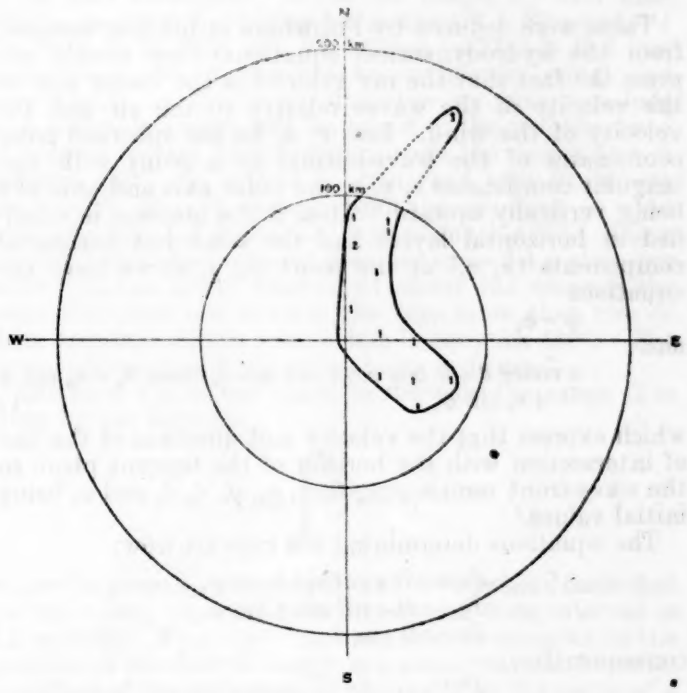

FIG. 4.—Regions of audibility of sounds of explosions of Asama, Oct. 26, 1913. (Author's Chart XVIIIa.)

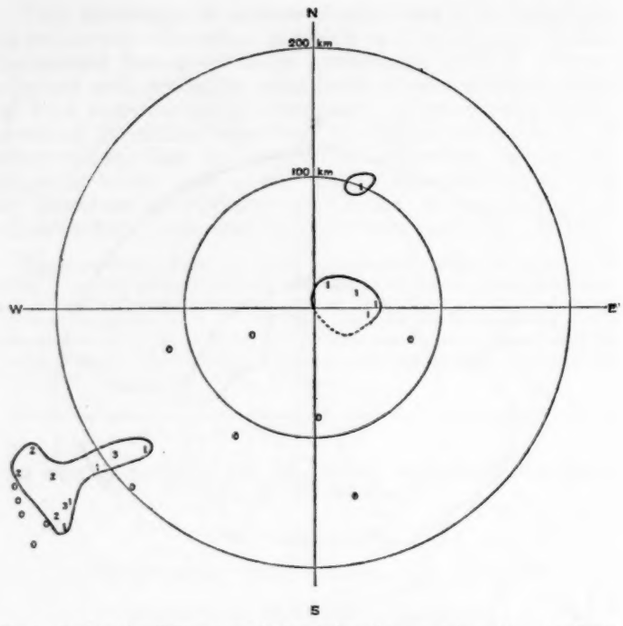

FIG. 5.—Regions of audibility of sounds of explosions of Asama, July 19, 1913. (Author's Chart XIIIa.)

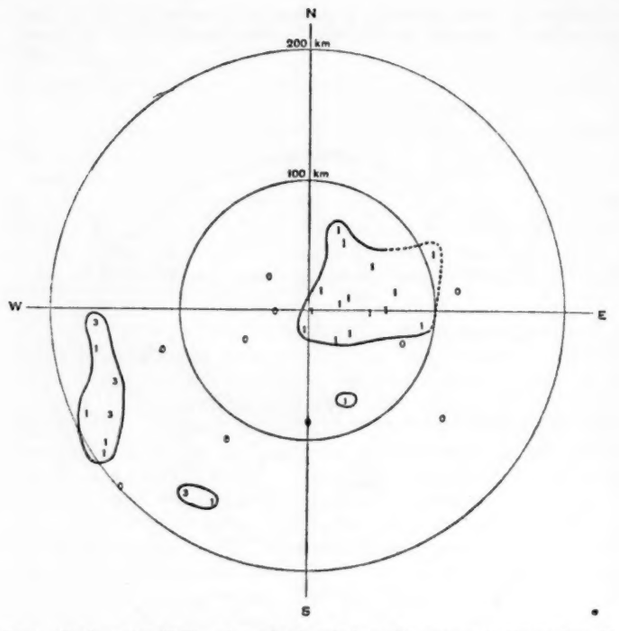

FIG. 6.—Regions of audibility of sounds of explosions of Asama, at 8h 10m on June 26, 1913. (Author's Chart VIIIa.)

and temperatures. Also when there are local convectional currents of air accompanying squalls or thunderstorms. The mathematical theory has not yet been developed for these cases, but Fujiwhara remarks that the phenomenon of rolling sound has a close relation with Helmholtzian waves.

A brief account will now be given of the way in which the shape of a region of audibility can be calculated when the meteorological conditions are known.

2. *Equations for the rays of sound.*

These were deduced by Fujiwhara in his first memoir, from the hydrodynamical equations; they simply express the fact that the ray velocity is the vector sum of the velocity of the waves relative to the air and the velocity of the wind. Let (θ, ϕ) be the spherical polar coordinates of the wave-normal at a point with rectangular coordinates x, y, z, the polar axis and axis of z being vertically upward. Then if the medium is stratified in horizontal layers and the wind has horizontal components $(u, v,)$ at the point (x, y, z) we have the equations

$$\phi = \phi_0$$

and

$$c \operatorname{cosec} \theta + u \cos \phi + v \sin \phi = c_0 \operatorname{cosec} \theta_0 + u_0 \cos \phi + v_0 \sin \phi, \quad (1)$$

which express that the velocity and direction of the line of intersection with the horizon of the tangent plane to the wave-front remain constant, u_0, v_0, c_0, θ_0 and ϕ_0 being initial values.[2]

The equations determining the rays are now:

$$dx = udt + cdt \sin \theta \cos \phi,$$
$$dy = vdt + cdt \sin \theta \sin \phi,$$
$$dz = cdt \cos \theta,$$

consequently

$$x + iy = \int_0^z \frac{1}{c}[c \tan \theta \, e^{i\phi} + (u + iv) \sec \theta]dz, \quad (2)$$

where θ is given by (1).

[2] *Rayleigh:* Theory of Sound. v. 2, p. 133.

3. *Conditions for reflection.*

If the wave be reflected at the level $z = \zeta$ we must have $\theta = 90°$ and so

$$c_0 \operatorname{cosec} \theta_0 - c = V \cos \alpha. \quad (3)$$

where $V\cos\alpha$ is the component along the horizontal projection of the wave-normal of the change in velocity of the wind as compared with that at the origin. In order that the wave may not be reflected at a lower level $c + V\cos\alpha$ must be greater than its value for all lower levels and so greater than its initial value c_0. We thus obtain the conditions

$$c_0 - c < V$$

and

$$\frac{d}{dz}(V\cos\alpha) > -\frac{dc}{dz}.$$

Fujiwhara replaces the last condition by the necessary condition that the vertical gradient of the horizontal wind velocity should be greater in absolute magnitude than $-\frac{dc}{dz}$.

Fujiwhara applies these conditions to an atmosphere built up of horizontal strata each a half kilometer in height, the gradients in each stratum being uniform. The constants are chosen so that the velocities at the boundaries between the strata agree with those observed at Ditcham[3] at 6:08 p. m. on May 21, 1907. The velocity of sound is calculated by using the mean temperatures for May over England.[4] In the following expressions $z, z_1, z_2, \cdots$ are measured in kilometers and each of them assumes values between 0 and $\frac{1}{2}$.

Stratum.	*c.*	$V\cos\alpha$.
0 —0.5	$337.0-2.2z$	$6.6\cos(259°-\phi)z$
0.5—1	$335.9-2.4z_1$	$3.3\cos(259°-\phi)+6.2\cos(33°-\phi)z_1$
1 —1.5	$334.7-2.4z_2$	$2.5\cos(322°-\phi)+6.6\cos(113°-\phi)z_2$
1.5—2	$333.5-2.6z_3$	$1.6\cos(71°-\phi)+3.6\cos(115°-\phi)z_3$
2 —2.5	$332.2-3z_4$	$3.2\cos(98°-\phi)+16.2\cos(41°-\phi)z_4$

[3] *Cave*, op. cit., p. 95.
[4] *Gold, E.* The international kite and balloon ascents. Geophys. mem. No. 5, p. 83. (Meteorol. Office, London.) 1913.

Since $c_0 - c > V$ for $z = 1.5$, there is no reflection at this level. Above $z = 2$ sound waves can be reflected because of the sudden increase of wind velocity and since the relative wind velocity has an azimuth of 56° the reflection takes place chiefly in a northeasterly direction. For the lower stratum ($z < 1$) the azimuth is about 259° and so the reflection takes place mainly in a westerly direction. Thus the sound is audible in a region extending somewhat to the west and probably in a detached region toward the northeast.

For $\phi = 259°$ we find that $c + V\cos\alpha$ increases with z up to $z = 0.5$ and then decreases; hence among the rays with azimuth 259° one which has its vertex at a height of 0.5 kilometer has the maximum range. For this ray

$$c_0 \operatorname{cosec} \theta_0 = 337 \operatorname{cosec} \theta_0 = 335.9 + 3.3 = 339.2.$$

The range is easily found from (2) to be 17.6 kilometers. Similarly for rays with azimuth 259° ± 30°, $c + V\cos\alpha$ has a maximum value at $z = 0.5$, and the rays with vertices at this height are given by

$$337 \operatorname{cosec} \theta_0 = 335.9 + 3.3 \cos 30° = 338.8.$$

The maximum range, R, is 19.6 kilometers. Similarly for rays whose azimuth is 210° from the north $R = 24.8$ kilometers.

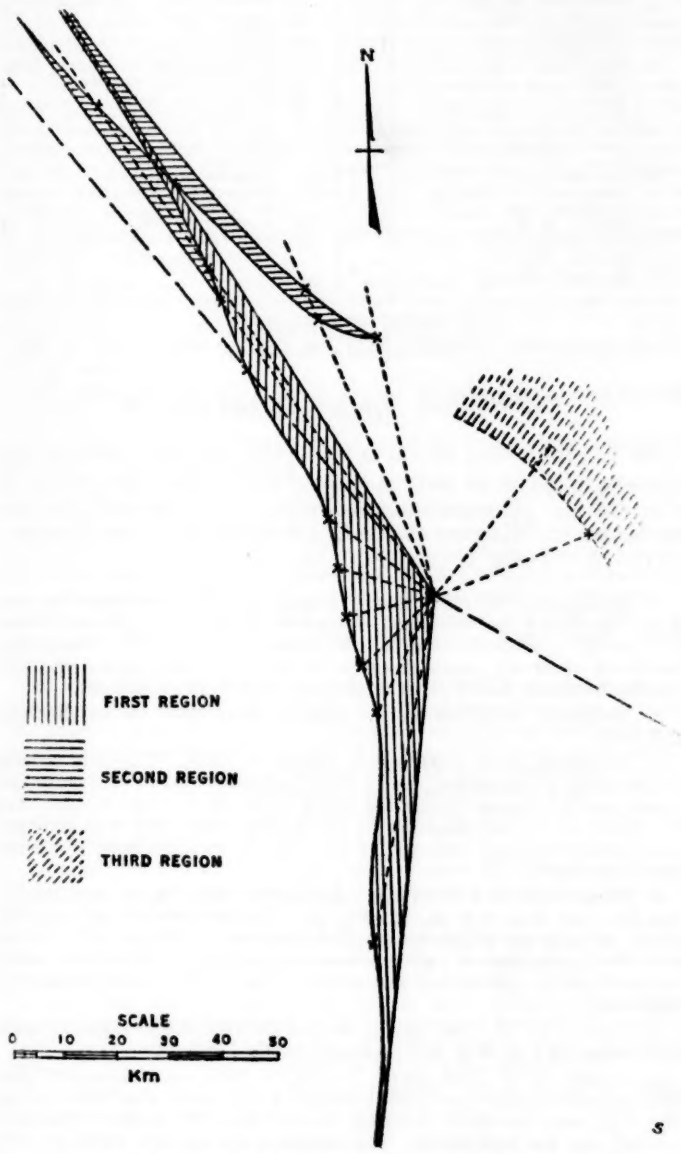

FIG. 7.—The calculated regions of audibility. (Author's fig. 2, p. 15.)

Calling the region of audibility associated with the wind in the stratum $z < 0.5$ *the first region*, we can find the extreme values of ϕ for this region by making $c + V\cos\alpha$ independent of z. The resulting equation

$$6.6\cos(259° - \phi) = 2.2$$

gives two values of ϕ, viz, $\phi_e' = 188°\ 30'$ and $\phi_e'' = 329°\ 30'$. We have $R = 0$ for $\phi = \phi_e'$ and $\phi = \phi_e''$, while $R = \infty$ for $\phi = \phi_e' + \epsilon$ and $\phi = \phi_e'' - \epsilon$, ϵ being a small positive angle.

The second region of audibility is associated with winds in the layer $0.5 < z < 1$. In order that reflection may take place $c + V\cos\alpha$ must increase with z and so ϕ must satisfy the inequality $6.2\cos(33° - \phi) > 2.4$, which gives

$$-34°\ 15' < \phi < 100°\ 15'.$$

The maximum value of $c + V\cos\alpha$ for any of these values of ϕ is attained when $z = 1$ and must be greater than c_0 or 337. This gives us the inequality

$$334.7 + 2.5\cos(322° - \phi) > 337,$$

therefore $\phi < -11°$ and so $-34°\ 15' < \phi < -11°$.
We have $R = \infty$ for the smallest value of ϕ, the corresponding value of R for the first region is found to be 66.6 kilometers.

The third region of audibility is associated with the winds above $z = 2$. In order that $c + V\cos\alpha$ may increase with z we must have $16.2\cos(41° - \phi) > 3$, therefore $321°\ 40' < \phi < 480°\ 21'$. For a ray with azimuth ϕ the minimum height ζ_m of the vertex is given by

$$4.8 + 3\zeta_m - 3.2\cos(98° - \phi) - 16.2\cos(41° - \phi)\ \zeta_m = 0.$$

Giving ϕ a value ϕ_m for which ζ_m has its minimum value $(\zeta_m)_m$, it is found by a graphical method that $\phi_m = 70°$, $(\zeta_m)_m = 2.17$ km. The corresponding range R is found to be 44.3 kilometers. A smaller range, $R = 31.5$ kilometers, is given by taking $340\sin\theta_0 = 337$. For $\sin\theta_0 = 1$ the range is 44.4 km and for $345\sin\theta_0 = 337$ it is 45.2 km. Since these two ranges are approximately equal and very nearly in the same direction we may conclude that a double report will be heard in the neighborhood of a point distant 45 kilometers from the origin and in azimuth 430°. It should be remarked that Fujiwhara assumes in his calculations that the gradient of wind velocity above 2.5 kilometers is in azimuth 430°. Below this level the wind velocity does not exceed 4 meters per second and so in an interval of about 135 seconds the cross wind can not deviate the rays more than two or three hundred meters from a line in azimuth 430°. The three regions of audibility are shown in figure 7.

The time the sound takes to describe the range R is given by the formula

$$t = 2\int_0^{\zeta} \frac{dz}{c} \sec\theta,$$

where θ is given by (1) and ζ by (3). Fujiwhara finds that $t_1 = 133.1$ sec., $t_2 = 137.8$ sec., thus the time interval is 2.3 seconds. Fujiwhara also makes a few remarks on the question of the flow of energy in a sound wave and studies the effect of the curvature of the earth on the range of a sound ray. He finds that the correction to allow for curvature is generally small, but in a rare exceptional case it may amount to as much as 42 per cent.

AURORAS OBSERVED DURING AUGUST, 1916.

AURORA OF AUGUST 26, 1916.

On referring to Wolfer's tables of relative sun-spot numbers[1] it is at once evident that during 1916–17–18 the solar system is again entering upon a period of maximum frequency of sun spots. Accordingly it is not surprising to find the aurora of increasingly frequent occurrence and of greater beauty and extent.

Up to the date of writing, the most extensive and gorgeous display of this year occurred on the night of August 26–27; as the following reports will show, this aurora has been reported from England, eastern and western United States, and occurred simultaneously at those and intermediate points. No doubt in time we shall hear of its appearance at many other points also. Readers will recall that the aurora of June 17, 1915, was visible simultaneously from Canadian stations down to Dunedin, New Zealand.[2] Next month it is hoped to present a map of the visibility of the aurora of August 26, 1916, for the United States, based on reports from Weather Bureau stations and the cooperative observers.

Table 1 presents a list of the regular Weather Bureau stations and shows at which stations the aurora was observed, while the reference number preceding the station name refers to the appropriate description given on following pages. Certain special reports by correspondents appear independently (p. 444).

TABLE 1.—*Index to Weather Bureau stations reporting the aurora of Aug. 26–27, 1916.*

[Numbers refer to description on pp. 440-443.]

Ref.	Station.	Obs.	Ref.	Station.	Obs.
.....	Abilene, Tex.	.....	.....	El Paso, Tex.	.....
.....	Albany, N. Y.	.....	12	Erie, Pa.	†
19	Alpena, Mich.	†	26	Escanaba, Mich.	†
.....	Amarillo, Tex.	.....	.....	Eureka, Cal.	.....
.....	Anniston, Ala.	.....	.....	Evansville, Ind.	.....
.....	Asheville, N. C.	.....	.....	Fort Smith, Ark.	.....
.....	Atlanta, Ga.	.....	.....	Fort Wayne, Ind.	.....
.....	Atlantic City, N. J.	.....	.....	Fort Worth, Tex.	.....
.....	Augusta, Ga.	.....	.....	Fresno, Cal.	.....
60	Baker, Oreg.	†	.....	Galveston, Tex.	.....
.....	Baltimore, Md.	.....	.....	Grand Forks, N. Dak.	*
.....	Bentonville, Ark.	.....	21	Grand Haven, Mich.	†
.....	Billings, Mont.	.....	.....	Grand Junction, Colo.	.....
.....	Binghamton, N. Y.	.....	22	Grand Rapids, Mich.	†
.....	Birmingham, Ala.	.....	25	Green Bay, Wis.	†
42	Bismarck, N. Dak.	†	.....	Hannibal, Mo.	.....
4	Block Island, R. I.	†	.....	Harrisburg, Pa.	.....
61	Boise, Idaho.	†	.....	Hartford, Conn.	.....
.....	Boston, Mass.	†	.....	Hatteras, N. C.	.....
.....	Buffalo, N. Y.	.....	52	Havre, Mont.	†
1	Burlington, Vt.	†	53	Helena, Mont.	†
.....	Cairo, Ill.	.....	.....	Honolulu, Hawaii.	.....
5	Canton, N. Y.	†	28	Houghton, Mich.	†
.....	Cape Henry, Va.	.....	.....	Houston, Tex.	.....
36	Charles City, Iowa.	†	44	Huron, S. Dak.	†
.....	Charleston, S. C.	.....	.....	Indianapolis, Ind.	.....
.....	Charlotte, N. C.	.....	.....	Iola, Kans.	.....
.....	Chattanooga, Tenn.	.....	.....	Jacksonville, Fla.	.....
.....	Cheyenne, Wyo.	.....	59	Kalispell, Mont.	†
23	Chicago, Ill.	†	.....	Kansas City, Mo.	.....
16	Cincinnati, Ohio.	†	32	Keokuk, Iowa.	†
13	Cleveland, Ohio.	†	.....	Key West, Fla.	.....
.....	Columbia, Mo.	.....	.....	Knoxville, Tenn.	.....
.....	Columbia, S. C.	.....	37	La Crosse, Wis.	†
14	Columbus, Ohio.	†	.....	Lander, Wyo.	.....
.....	Concord, N. H.	.....	17	Lansing, Mich.	†
.....	Concordia, Kans.	.....	.....	Leadville, Colo.	.....
.....	Corpus Christi, Tex.	.....	.....	Lewiston, Idaho.	.....
.....	Dallas, Tex.	.....	.....	Lexington, Ky.	.....
33	Davenport, Iowa.	†	.....	Lincoln, Nebr.	.....
.....	Dayton, Ohio.	.....	.....	Little Rock, Ark.	.....
.....	Del Rio, Tex.	.....	.....	Los Angeles, Cal.	.....
.....	Denver, Colo.	.....	.....	Louisville, Ky.	.....
34	Des Moines, Iowa.	†	20	Ludington, Mich.	†
.....	Detroit, Mich.	.....	11	Lynchburg, Va.	*
41	Devils Lake, N. Dak.	†	.....	Macon, Ga.	.....
.....	Dodge City, Kans.	.....	30	Madison, Wis.	†
.....	Drexel, Nebr.	.....	.....	Manteo, N. C.	.....
35	Dubuque, Iowa.	†	27	Marquette, Mich.	†
40	Duluth, Minn.	†	.....	Memphis, Tenn.	.....
.....	Eastport, Me.	.....	.....	Meridian, Miss.	.....
.....	Elkins, W. Va.	.....	.....	Miami, Fla.	.....

[1] MONTHLY WEATHER REVIEW, July, 1915, 43:314-5.
[2] MONTHLY WEATHER REVIEW, 1915, 43:445, 546, 596.

TABLE 1.—*Index to Weather Bureau stations reporting the aurora of Aug. 26–27, 1916*—Continued.

[Numbers refer to description on pp. 440-443.]

Ref.	Station.	Obs.	Ref.	Station.	Obs.
51	Miles City, Mont.	*	.....	St. Louis, Mo.	.....
24	Milwaukee, Wis.	†	39	St. Paul, Minn.	†
38	Minneapolis, Minn.	†	.....	Salt Lake City, Utah.	.....
.....	Mobile, Ala.	.....	.....	San Antonio, Tex.	.....
56	Modena, Utah.	†	.....	San Diego, Cal.	.....
.....	Montgomery, Ala.	.....	.....	Sand Key, Fla.	.....
43	Moorhead, Minn.	†	.....	Sandusky, Ohio.	.....
.....	Mount Tamalpais, Cal.	.....	.....	Sandy Hook, N. J.	.....
.....	Nantucket, Mass.	.....	.....	San Francisco, Cal.	.....
.....	Narragansett Pier, R. I.	.....	.....	San Jose, Cal.	.....
.....	Nashville, Tenn.	.....	.....	San Juan, Porto Rico, W. I.	.....
.....	New Haven, Conn.	†	.....	San Luis Obispo, Cal.	.....
.....	New Orleans, La.	.....	.....	Santa Fe, N. Mex.	.....
.....	New York, N. Y.	.....	18	Sault Sainte Marie, Mich.	†
.....	Norfolk, Va.	.....	.....	Savannah, Ga.	.....
2	Northfield, Vt.	*	.....	Scranton, Pa.	.....
.....	North Head, Wash.	.....	62	Seattle, Wash.	*
.....	North Platte, Nebr.	.....	.....	Sheridan, Wyo.	.....
.....	Oklahoma, Okla.	.....	.....	Shreveport, La.	.....
47	Omaha, Nebr.	†	46	Sioux City, Iowa.	†
6	Oswego, N. Y.	†	58	Spokane, Wash.	†
.....	Palestine, Tex.	.....	.....	Springfield, Ill.	.....
15	Parkersburg, W. Va.	†	.....	Springfield, Mo.	.....
.....	Pensacola, Fla.	.....	7	Syracuse, N. Y.	†
31	Peoria, Ill.	†	63	Tacoma, Wash.	*
.....	Philadelphia, Pa.	.....	.....	Tampa, Fla.	.....
.....	Phoenix, Ariz.	.....	.....	Tatoosh Island, Wash.	.....
.....	Pierre, S. Dak.	.....	.....	Taylor, Tex.	.....
.....	Pittsburg, Pa.	.....	.....	Terre Haute, Ind.	.....
55	Pocatello, Idaho.	*	.....	Thomasville, Ga.	.....
.....	Point Reyes Light, Cal.	.....	.....	Toledo, Ohio.	.....
.....	Port Angeles, Wash.	.....	.....	Tonopah, Nev.	.....
.....	Port Huron, Mich.	.....	49	Topeka, Kans.	†
.....	Portland, Me.	.....	.....	Trenton, N. J.	.....
.....	Portland, Oreg.	.....	50	Valentine, Nebr.	†
3	Providence, R. I.	†	.....	Vicksburg, Miss.	.....
.....	Pueblo, Colo.	.....	.....	Wagon Wheel Gap, Colo.	.....
.....	Raleigh, N. C.	.....	59	Walla Walla, Wash.	†
.....	Rapid City, S. Dak.	.....	9	Washington, D. C.	†
.....	Reading, Pa.	.....	29	Wausau, Wis.	†
.....	Red Bluff, Cal.	.....	.....	Wichita, Kans.	.....
.....	Reno, Nev.	.....	.....	Williston, N. Dak.	†
10	Richmond, Va.	*	.....	Wilmington, N. C.	.....
8	Rochester, N. Y.	†	.....	Winnemucca, Nev.	.....
.....	Roseburg, Oreg.	.....	.....	Wytheville, Va.	.....
.....	Roswell, N. Mex.	.....	45	Yankton, S. Dak.	†
.....	Sacramento, Cal.	.....	54	Yellowstone Park, Wyo.	†
.....	Saginaw, Mich.	.....	.....	Yuma, Ariz.	.....
48	St. Joseph, Mo.	†			

† Described under number given.
* Recorded but not described.
.. Not observed at that station.

Reports from Weather Bureau stations.

In the following extracts the standard time used at the station is given in curves immediately after the name of the station. Geographical coordinates of the stations can be found in "Report of the Chief of the Weather Bureau, 1913–14," Table I, pages 30–34.

1. *Burlington, Vt.* (75th mer.), August 26, 1916.—Aurora first observed at 9:50 p. m. consisted of narrow grayish arch; azimuth from 165° to 195°. Altitude of arch at highest point about 20°. Numerous streamers observed, some shooting to zenith. The display was unusually brilliant, but of short duration. Ended at 10:20 p. m.

2. *Northfield, Vt.* (75th mer.).—Auroras were observed on the 26th and 28th.

3. *Providence, R. I.* (75th mer.), August 26, 1916.—The only optical or electrical phenomenon, aside from lightning, observed during the month was an aurora during the night of the 26th. The display was not observed by any member of the station force, but was reported from various sources, believed to be reliable, to have been of exceptional brilliancy.

4. *Block Island, R. I.* (75th mer.), August 26, 1916.—An auroral display was observed from 8 p. m. to 10 p. m. The altitude of the arch was about 20°, and the azimuth extended from about 120° to 220°. There were lively streamers of pale green ascending from a few degrees below the arch to an altitude of about 45°. The whole display was very brilliant.

5. *Canton, N. Y.* (75th mer.), August 26, 1916.—Faint auroral arch and streamers 8 to 10 p. m.; obscured partly by clouds.

6. *Oswego, N. Y.* (75th mer.), August 26, 1916.—An unusually brilliant auroral display was visible from 8 p. m. until after 10:45 p. m. The light was devoid of coloring, except near the horizon, where a reddish tint was noticeable. The extent of the display, reaching as it

did from west to east and from the horizon to south of the zenith, and its intense activity were the features. Broad waves of whitish light flashed incessantly from the horizon up to and past the zenith, but there was practically no lateral movement. It is seldom that such rapid movement of the waves of light is seen.

7. *Syracuse, N. Y.* (75th mer.), August 26, 1916.—An aurora was reported to have been visible from 8 to 10 p. m.

8. *Rochester, N. Y.* (75th mer.), August 26, 1916.—An aurora which occurred on the 26th is excellently described in the following article from the "Democrat and Chronicle," by Prof. Latimer J. Wilson, in charge of the Bausch & Lomb Observatory:

"From shortly after dark until 9:30 o'clock last Saturday evening an aurora of unusual brilliance spread across the entire northern sky and extended as far as the constellation Sagittarius in the south. Observations made at the Bausch & Lomb Observatory disclosed several extraordinary features attending the display.

"The first sign of anything out of the ordinary in the heavens was a very noticeable glow in the northeast and peculiar horizontal streaks of what at first appeared to be thin clouds of haze directly overhead. A moment's consideration showed that the haze was subject to the most remarkable changes. It looked somewhat as though a battery of small searchlights were trained upon the overhead part of the sky, striking through the haze and lighting it with slender or broad beams of pale light. The beams came from the northeast, the northwestern section of the sky being covered by a large gray cloud. The cloud drift seemed generally in a northeasterly direction and was rather rapid.

"Notwithstanding the brilliance of the phenomenon, probably few city people saw it because of the glare of the street lights. A keen observer stepping into a dark corner of his lawn where shrubbery screened the electric lights from his eyes would have seen the background of the aurora, glowing between the breaks in the northern cloud covering. Perhaps the brightest part of the phenomenon occurred at 9 o'clock, when the clouds which had hidden the north and northwestern part of the heavens began to clear away in places.

"The effect was very similar to bright moonlight streaming in crepuscular rays from between the clouds. A continuous shifting of the rays betrayed their auroral origin. Pulsations of rosy light flashed across the apparently low masses of haze. These masses were quite distinct from the small cloud groups which resembled cirrus forms and which were drifting somewhat less rapidly toward the northeast. The vaporous accumulations upon which the aurora was discerned grew very bright for a few minutes, and ribbons of the rosy light waved across them in the form of an arc."

9. *Washington, D. C.* (75th mer.), August 26, 1916.—An aurora, brilliant at intervals, was reported to have been observed from 9 p. m., August 26, to 12:45 a. m., August 27. It was from 3° to 5° in width, with pulsating shafts of light, or "merry dancers," extending upward to the zenith.

10. *Richmond, Va.* (75th mer.), August 26, 1916.—An aurora borealis was observed on the evening of the 26th.

11. *Lynchburg, Va.* (75th mer.), August 26, 1916.—Aurora observed to-night. [No details given.]

12. *Erie, Pa.* (75th mer.), August 26, 1916.—A pronounced auroral display occurred from about 11 p. m. until midnight. The streamers reached clear to the zenith and somewhat resembled the rays from a powerful searchlight. Telegraphic reports indicate that it was observed as early at 7 p. m. in other cities, but local cloudiness prevented its observation that early. It attained its greatest development about midnight. The altitude of the crown was about 20°, while the extremity of the streamers was 90°. The azimuth was about 110° to 250°.

13. *Cleveland, Ohio* (75th mer.), August 26, 1916.—At 9 p. m. a telephone message from Cleveland Heights called attention to the presence of "searchlights" in the north. At station no lights of this description could be seen in that or any other direction. However, from reliable information received from other sources in the city's suburbs, it is evident that an auroral display of short duration took place.

14. *Columbus, Ohio* (90th mer.), August 26, 1916.—An aurora was observed to-night.

15. *Parkersburg, W. Va.* (75th mer.), August 26, 1916.—During the evening an aurora was observed, but on account of cloudiness observations were made at short intervals only.

16. *Cincinnati, Ohio* (90th mer.), August 26, 1916.—A glow of light was observed in the northeast from 8:55 p. m. to 9:15 p. m., being brightest about 9:05 p. m. The light appeared to be from the aurora borealis, but was not distinct enough to make definite observations. At 9:05 p. m. a bright streak of light extended from 10° south of the zenith to near the western horizon. This appeared to be a cloud formation and disappeared rapidly within two or three minutes.

17. *Lansing, Mich.* (90th mer.), August 26, 1916.—A brilliant aurora was observed to-night between 10 and 12 p. m.

18. *Sault Ste. Marie, Mich.* (90th mer.), August 26, 1916.—Aurora visible from 7:25 p. m., ending about 11:15 p. m. At 7:40 p. m. until 8 p. m. the display was like a cirro-stratus veil, covering the entire sky, waving back and forth at short intervals. Neither arch nor colors were observed.

19. *Alpena, Mich.* (90th mer.), August 26–27, 1916.—Beginning on the evening of the 26th and continuing into the morning of the 27th, one of the most magnificent, and to many awesome, auroral displays ever observed at this station was witnessed. It was first noticed just after dark in the east. As darkness came on a great band of straw-colored light appeared across the firmament from east to west, spreading 40° north of the zenith and 10° south. This band of light had a steady movement to the southern horizon and reached it in about 20 minutes. By this time the whole heavens were covered with a sheet of whitish light which was bright and steady. Shortly this broke up into patches of iridescent light, which formed and vanished with tremendous speed in all parts of the heavens. Occasionally these patches were of indescribably fantastic shapes, joining and spreading to the zenith, forming a dome. The southern horizon was as bright as the northern. The display continued with irregular grandeur until some time after 2 a. m. Many people who were on Lake Huron spoke of the beautiful reflection of the display from the water.

20. *Ludington, Mich.* (90th mer.), August 26, 1916.—Brilliant aurora beginning about 8 p. m. and continuing practically all night until about 4 a. m. [of August 27]. Definite observations were continued until nearly midnight. No distinct arch was observed, although clouds in the north most of the evening would have obscured the arch had one existed. The display consisted mainly of whitish and yellowish sheets, streaks, bands, and rays at places all along the north, east, and west quarters of the horizon and up to the zenith and far beyond [toward] the south. At times pronounced flashing occurred, especially in the northeast and northwest and in addition to whitish and yellowish, reddish, greenish, and violet colors appeared. At about 10:45 to 11 o'clock a pronounced rosette or crystal-like formation was observed overhead about 10° southeast of the zenith; it had a dark center and whitish streaks fully 10° to 15° long radiating in every direction. One or more similar formations are said to have occurred earlier in the evening. At about 10 o'clock a whitish band spanned the sky from east to west nearly through the zenith, and dark streaks at intervals of about 30° stretched from the band toward the south. However, nearly all the sheets and streaks during the display were vertical and from north to south.

21. *Grand Haven, Mich.* (90th mer.), August 26, 1916.—Streamers of light, apparently from aurora light, played over about seven-tenths of the sky above the horizon beginning between 7 and 8 p. m., and continuing to nearly midnight.

22. *Grand Rapids, Mich.* (90th mer.), August 26, 1916.—The aurora of to-night was very brilliant and lasted from dark till near midnight. While no color was observed it was as brilliant as a powerful searchlight, the beams frequently attaining the zenith and traveled in curtain-like waves very rapidly from west to east, dimming and glowing at frequent intervals. Its base was a dark arch extending about 10° above the horizon. Its influence was first felt by wire companies about 5 p. m., and from that time up to near midnight telegraph and telephone service, especially east and west, was interrupted, and at times almost suspended. Azimuth 90° to 225°, altitude 90°.

23. *Chicago, Ill.* (90th mer.), August 26, 1916.—A very brilliant display of the aurora borealis was seen to-night. The aurora began about 7:30 p. m. and continued until after 11 p. m. The whitish arc of light could be plainly seen in the north and the quivering, rapid-moving beams of light extended almost to the zenith. It was reported that telephone and telegraph transmission was slightly affected north and east of Chicago.

24. *Milwaukee, Wis.* (90th mer.), August 26, 1916.—An auroral display was observed to-night from 8:30 p. m. to about midnight. There seemed to be no well-defined ray of light but the whole sky from west to north seemed to be lit up with light waves that rose and receded like the flames of a fire. It interfered somewhat with telegraphic communication.

25. *Green Bay, Wis.* (90th mer.), August 26, 1916.—Aurora 26–27th, first observed at 8:50 p. m. and continued to 12 midnight. First appeared as flashing streamers of white light, from about 15° above the horizon to the zenith, and extending from about 90° to 200° azimuth; between 135° and 160° the aurora was partly obscured by a dark bank of clouds. From 10:40 p. m. to midnight the streamers appeared to be shooting from all directions [toward] a point near the zenith, and forming a brilliant corona; the streamers appeared broader and more clearly defined on the north and west sides. It became less active after 12 midnight and disappeared at 12:45 a. m. of the 27th.

26. *Escanaba, Mich.* (90th mer.), August 26, 1916.—An auroral display was observed at 7:45 p. m. The phenomenon invested almost the entire sky, and seemed to be centered directly overhead, giving

the appearance of a vast parasol. The light waves pulsated in concentric rings which gradually were drawn in toward the center, intensifying its brightness. An arch of about 10° altitude, and about 135° to 225° in azimuth was plainly marked across the northern horizon. Greenish light predominated with an occasional tinge of red. It is reported that the phenomenon continued well after midnight, though it was not under the observation of the observer after 9 p. m.

27. *Marquette, Mich* (90th mer.), August 26, 1916.—A sky-covering, beautiful silver-colored aurora was seen by all on the 26th.

28. *Houghton, Mich.* (90th mer.), August 26, 1916.—Aurora observed to-night, consisting of a greenish arch about 30° in altitude and 60° in azimuth; from this arch various-colored and rapidly moving streamers reached beyond the zenith. The display lasted for nearly two hours.

29. *Wausau, Wis.* (90th mer.), August 26, 1916.—A very brilliant aurora was observed from 8:15 to 11:30 p. m. At 8:25 p. m. the aurora became very brilliant and, as near as could be seen, came from every quarter of the horizon. The sheets of light shot upward until they met in the zenith, forming there sometimes three and at other times a four pointed star. This star had the appearance of being formed of bright cirrus clouds. In looking toward the zenith one had the impression of looking up into a gigantic dome. This ended about 8:50 p. m., but several displays of nearly equal brilliance occurred several times during the evening. The entire northern sky remained brilliant until about 11:30 p. m. when [the light] waned.

30. *Madison, Wis.* (90th mer.), August 26, 1916.—An unusually brilliant aurora observed from dark. Many streamers rising from auroral arch in north. Draperies overhead and in east shimmered and flashed, the change being very rapid. No color observed. . . . Aurora of the 26th probably visible to about 2 a. m. of the 27th.

31. *Peoria, Ill.* (90th mer.), August 26, 1916.—A striking display of aurora borealis, composed of glow and streamers with considerable drifting, flashing, dancing, and flickering. Coloring generally whitish with a little rainbow tinting about 9 to 9:15 p. m. A noticeable drifting from about east-northeast and at the same time a southward shift of the whole formation. About 10 p. m. the front or higher portion of white streamers had formed a sort of band near the zenith, extending from about azimuth 95° to azimuth 280°, while the display farther north had decreased in brilliance. (Perhaps this band-like appearance was due to perspective of streamers standing nearly vertical in the sky.) Later the band formation shifted 10° or 15° south of the zenith, retaining its original trend. A westward drift within the band was at all times noticeable, but the band at no time reached lower in the west than altitude 40°.

32. *Keokuk, Iowa* (90th mer.), August 26, 1916.—Aurora first observed at 8:30 p. m., arch extending from northwest to northeast, color changing between red and green, streamers shooting up to about 30° above the horizon, in the center of the arch, and undulating horizontally.

At 9 p. m. a peculiar band of grayish color, resembling thin stratus cloud, was observed. Band at an elevation of about 45° above the southern horizon, some 3° in width, reached across the sky, which was perfectly clear, from near the western to near the eastern horizon. This band was still plainly visible at 11 p. m. The aurora was brightest between 11 p. m. and midnight.

33. *Davenport, Iowa* (90th mer.), August 26, 1916.—An aurora, which was first observed at 8:40 p. m., prevailed until after midnight. A pale yellow glow, resembling the reflected light over a large city, extended upward to about 5° south of the zenith. No arch was observed.

34. *Des Moines, Iowa* (90th mer.), August 26, 1916.—A rather well-defined aurora borealis was observed at night. The illumination was first noted about 8:30 p. m., and it was still in evidence at 11 p. m. The most pronounced feature of the display was the flashing of the streamers; these at times extended upward well toward the zenith. About 9 p. m., as the display became less intense for a time, a whitish appearing arc or band of light was noted extending across the sky almost from horizon to horizon, from a point a little north of west to a point a little south of east. When first seen, the crown or top of the arc was almost overhead; but the whole arc drifted southward, and by 9:15 p. m. had disappeared. At the time of disappearance the top of the arc was probably 25° south of the zenith. The width of the arc was rather uniform throughout its length, being about 2°.

35. *Dubuque, Iowa* (90th mer.), August 26, 1916.—The finest aurora borealis witnessed at this station in many years occurred to-night. It began in the early evening and lasted several hours (first observed by the writer at about 7:30 p. m., was most brilliant around 8:30 p. m., and was faint after 9:30 p. m.). Consisted of quivering white beams which came out of the north. These beams were distinct and reached to the zenith and about 10° or 15° beyond. The entire northern half of the sky was bright, and from the horizon to about 30° above the sky was greenish, resembling a curtain. The most distinct green was in the extreme north. The display overhead was beautiful, there being numerous patches of quivering light.

36. *Charles City, Iowa* (90th mer.), August 26, 1916.—An auroral display observed from 7:48 p. m. until midnight. When it was first noticed, there was a light-gray arch; its base extended from 135° to 225° azimuth, the crown reaching 20° altitude. The arch disappeared at 8:20 p. m. From about 8:20 p. m. until 11:40 p. m. there appeared streaks and groups of white to gray in color, the former resembling "mares' tails," the latter denser cirri formations. These lights or groups of lights at times filled the sky from the zenith down to the horizon between 110° and 230° azimuth; again there would be only one or two "mares' tails," but always each separate formation seemed to emit light waves which flickered and drifted from their sources. At the same time there appeared stronger shafts of light, much like electric headlights when seen from a distance at right angles to the rays. These did not always originate in any of the formations, generally first appearing at points where the blue sky could be distinguished. Usually these "headlight" shafts moved up toward the zenith, but some of them were extended at angles to that direction. When extended to their full length, they remained stationary for a short time; then the shaft began fading at the point in the sky where it originated, gradually shortening until the outward, or upward, end was the last seen of it. This characteristic shortening made the shaft appear to drift away from its source. When the sky was well filled, within the limit stated, the combined light from the different sources was near that of the full moon. In unlighted rooms with open windows people and objects on the other side of the street were reflected from mirrors.

Several cirri formations were observed during the afternoon and 4/0 Ci. was recorded at the 7 p. m. observation. The resemblance to those clouds noted in the auroral display may have been due to their presence at that time and illumination. However, a careful watch was maintained for them when the intervening light was weak enough to permit seeing the blue beyond it, and no clouds were seen; also, had they been in that zone it is likely some would have been in other sections of the sky, and there was no display elsewhere.

37. *La Crosse, Wis.* (90th mer.), August 26, 1916.—An unusually brilliant auroral display was observed during the evening of the 26th and the morning of the 27th. At 8:30 p. m. of the 26th northern-lights streamers were observed above the northwestern horizon. By 9 p. m. the sky was nearly covered by quivering rays or beams, which continued with varying degrees of brilliancy after midnight. The display caused considerable excitement on account of its extent and its brilliant flashing and darkening.

I have not heard of any person who claims to have seen a display of such extent and brilliancy. One man thought it a searchlight playing over the sky, and a little girl was overheard calling, "Mother, come out and see the lightning all over the sky."

38. *Minneapolis, Minn.* (90th mer.), August 26, 1916.—An unusual auroral display was observed beginning shortly after 8 p. m. It then covered the northern half of the sky from azimuths 80° to 280°. The display took on several forms. There were several more or less well-defined arches in the north-northeast, with streaks and streamers pointing upward from the east, north, and west and converging at a central point or apex about 10° south of the zenith, where the streaks of light were of shorter length and arranged themselves around this apex similar to pieces of iron filings in a field of magnetic force. There were also patches of irregular cloudlike masses of light scattered over the northern sky. Very few of the streamers had any "shooting" upward motion, but there was a continuous wavelike motion from all sides toward the apex running over the light places and streaks. The display continued until after 12 midnight with varying intensity. There were no eastward-westward motions along the arches and very little coloring.

39. *St. Paul, Minn.* (90th mer.), August 26, 1916.—There was a fine auroral display from about 8 p. m. to near midnight. As noted by the official in charge, at 8 p. m. it extended from about azimuth 60°, by the north to about azimuth 270°, extending to about altitude 85°, as streamers of whitish light, with occasional rose tints. At about 8:25 p. m. a green tint in streamers about 40° high, near azimuth 200°; the display quickly extended over the sky to near the southern horizon, with an apex slightly south of the zenith.

The display constantly varied, with dancing waves of light alternating with streamers near the western to north of the eastern horizon. The center of the display appeared to be near azimuth 180°. No dark segment could be distinguished prior to 10 p. m., nor at intervals until near midnight.

40. *Duluth, Minn.* (90th mer.), August 26, 1916.—A very brilliant aurora observed about 10 p. m. from azimuth 150° to about azimuth 225°. The altitude of the highest shafts of light was about 60°. These perpendicular shafts were of a greenish white color and moved back and forth horizontally, giving the appearance of a waving curtain.

41. *Devils Lake, N. Dak.* (90th mer.), August 26, 1916.—The * * * aurora was a magnificent display of large proportions. It was first observed at 9 p. m. and was still [pulsating] at 11:30 p. m. Its position was unusual, spanning the southern sky at high altitude, its center nearly reaching the zenith. Its azimuth was about 60° to 270°. The colors were of great variety, the more predominant ones being pale green, violet, and purple.

42. *Bismarck, N. Dak.* (90th mer.), August 26, 1916.—Aurora observed from 10 p. m. to midnight; an unusually brilliant display, covering almost the whole sky from 11 p. m. to midnight.

43. *Moorhead, Minn.* (90th mer.), August 26, 1916.—An aurora of unusual brilliancy was seen. As first observed at 9:25 p. m. it consisted of a diffused light over the west and northwest, with faint streamers reaching to the zenith. Objects were visible as by moonlight. At 11 o'clock p. m. the observer was awakened by violent ringing of the doorbell by two men who seemed terrified and asked for an explanation of the wonderful light in the heavens. The whole sky was illuminated with streamers and waves of light moving very rapidly from west to southwest, with the whole northern sky as brilliant as a clear sunrise, just before the sun appears. This phenomenon extended over the whole sky and was indescribably grand and awe inspiring. The display lasted until about midnight, when it gradually disappeared.

The following is quoted from the Moorhead Daily News of Monday, August 28, 1916: "For several hours Saturday night one of the most brilliant auroræ ever witnessed at this period of the year was seen in Moorhead. Great spires of light extended from the horizon and stabbed the heavens like sheets of flame.

"For sometime the center of the display was directly overhead, from which luminous streamers extended in all directions, some of the shafts ending in great patches of light that shimmered and fluctuated like the flames of a great conflagration.

"* * * The electric display seriously affected telegraph communication in the Northwest."

44. *Huron, S. Dak* (90th mer.)—Auroras were observed during the late evenings of the 26th and 28th. On both nights a glow was observed in the north but streamers were seen only on the 26th, and then in the northeast.

45. *Yankton, S. Dak.* (90th mer.), August 26, 1916.—Aurora from 8:20 p. m. to 11:30 p. m. It first appeared as a whitish light in the northern sky, extending from azimuth 130° to 220° and with an elevation at its apex of about 20°. At 9 p. m. the light began to shoot toward the zenith rapidly in streamers, converging at a point about 70° above the direct northern horizon and taking on a light yellowish color. The streamers disappeared about 10 p. m., the aurora then forming an arch of light across the sky, in the same relative azimuth position first noted and with an elevation of about 40°. The arch continued until 10:45 p. m., after which time the light gradually diminished, finally disappearing at 11:30 p m.

46. *Sioux City, Iowa* (90th mer.), August 26, 1916.—An auroral display of extreme beauty was observed from 8:30 to 11 p. m. The converging shafts of light several times almost reached a boreal crown a few degrees south of the zenith. At intervals of 20 to 30 minutes it would fade away, and then gradually increase in strength until the shafts nearly reached the zenith, when waves or pulsations of light would rise like the folds of a waving flag. It was a clear white light until nearly 10:30, when it assumed a reddish tinge. Many said it was the most brilliant display ever seen here.

47. *Omaha, Nebr.* (90th mer.), August 26, 1916.—An auroral display was observed, lasting from 8:15 p. m. to after 10 p. m. There was a light like moonrise in the north, with pink on the west side and green on the east. Flickering streamers of light reached at times as high as 70° toward the zenith. The display was about 100° in width, and extended from about 130° to 230°.

48. *St. Joseph, Mo.* (90th mer.), August 26, 1916.—An aurora was observed at 8:20 p. m. and at intervals until past midnight. At 8:30 p. m. beams of light extended from a large cloud of light on the northern horizon to the vicinity of the north star. Smaller clouds of light were also noted in the northwest and northeast. Very faint illuminations, somewhat similar to distant lightning, were seen at frequent intervals shortly before midnight on the upper edge of the cloud of light on the northern horizon.

49. *Topeka, Kans.* (90th mer.), August 26, 1916.—Aurora reported on credible authority as having been seen from 11 p. m. to 11:20 p. m. At times it spread out fan-shaped in the northern sky as high as 30° and streamers were observed extending as high as 60° above the horizon.

50. *Valentine, Nebr.* (105th mer.), August 26, 1916.—A beautiful auroral display occurred to-night. It was first observed at 10 p. m. Azimuth 80° to 120°. There were a few shafts extending to near the zenith, but most of the display was in the form of bright flashes extending from the horizon to about 45° altitude. The display was faint when last observed at 10:50 p. m., and it is believed ended before midnight. The aurora probably began early in the evening, but clouds obscured the view.

51. *Miles City, Mont.* (105th mer.), August 26, 1916.—Aurora. [No description.]

52. *Havre, Mont.* (105th mer.), August 26, 1916.—The most beautiful exhibit observed here for many years prevailed to-night between 9 o'clock and 12 midnight. At 9:20 p. m. the aurora appeared with the dark segment and luminous beams of bright light of a greenish and rosy hue and also of pale yellow color appearing over that portion of the segment in the northwest, and three parallel arches extended entirely across the sky from east to west, having a breadth of about 10°. The largest arch had its west end at azimuth of about 100° and its east end 315°, with summit 45° south of the zenith, nearly the whole sky being covered with auroral exhibit of different appearances. There were recurring fits of brilliancy and at 10 p. m. waves of light rolled up toward the zenith, luminous beams prevailed. There was no corona.

53. *Helena, Mont.* (105th mer.), August 26, 1916.—A very beautiful aurora was observed at 8:15 p. m. and it cloud be plainly seen until 11 p. m. The light was more intense in the western half and the pulsating streamers changed very rapidly about 9 p. m. At times the light was very strong and by proper exposure ordinary printed matter could be read. The altitude of the crown of the arch of light was about 80° and the azimuths of the extremities were approximately 150° and 210°. Cooperative observers over the State report that the aurora was the brightest observed in years.

54. *Yellowstone Park* (105th mer.), August 26, 1916.—An auroral display was noted from 8:45 p. m. to 10:15 p. m. The aurora appeared in the north with beams and streamers of yellowish light extending from the horizon to about 20° to 35° altitude. An arc of more whitish light appeared from about 45° altitude almost to the zenith. The display changed but slightly during the period it was visible.

55. *Pocatello, Idaho* (105th mer.), August 26, 1916.—Aurora. [No details given.]

56. *Modena, Utah* (105th mer.), August 26–27, 1916.—A faint aurora was observed at 10:30 p. m. of the 26th and ending during the morning of the 27th. It consisted of vibrating streamers which reached to an average height of 30°. The streamers seemed to radiate from a point below the horizon directly in the north and extended along the horizon 20° from each side of azimuth 180°.

57. *Kalispell, Mont.* (105th mer.), August 26, 1916.—An aurora was observed to-night beginning about 8:45 p. m. with a few slender streamers shooting nearly to zenith from out the northwest horizon, at which time an indistinct band of white light was noticeable extending across the sky, dimming the light of the stars forming the Big Dipper and Cassiopeia; this band prevailed about half an hour. A second band of a brighter, whiter light appeared in the course of the next half hour below Polaris, extending from the northwest to east, gradually moved upward and southward, increasing to a band of 5° in width when nearing β in Scorpio well to the south of the zenith about 10 p. m. The band was brightest at the easternmost end. A few dull-white streamers began shooting up in the northwest in succession around to the east, where the brightest ones were seen, an incandescent white, tinged with red.

About 9:40 p. m. a meteor of dull yellowish white, lasting about two seconds, originated near Boötes, disappearing near the second star in the handle of the Great Dipper. Its fall as compared with the horizon was less than half a degree from the straight south-north line. There was a diminution in brightness of this meteor when passing the auroral band prevailing at the same time. It left no tail or streamer during passage.

58. *Spokane, Wash.* (120th mer.), August 26, 1916.—At 8 p. m. an aurora borealis was observed, apparently having an azimuthal extent of 135°, from 135° to 270°. No well-defined auroral arch was noted, but luminous beams, "merry dancers," intermittently flashed up from the "dark segment," frequently passing the zenith. Display disappeared before 5 a. m. observation of the 27th. Reported that telegraph wires were somewhat affected from 4:30 p. m. until midnight.

59. *Walla Walla, Wash.* (120th mer.), August 26, 1916.—An auroral display was witnessed between 8 and 10:30 p. m. A broad arc of white light extended above the horizon, its center being east of Polaris. Vertical streamers of light shot up at intervals above the bands of white light, being at times so numerous as to form a curtain of light across the northern sky. The display was quite brilliant during the first hour.

60. *Baker, Oreg.* (120th mer.), August 26, 1916.—An aurora or northern lights observed from 9 p. m. to 11 p. m., colored streamers shooting up in all directions at frequent intervals, spreading over the north, northwest, and northeast sky; lights not very brilliant.

During the display a narrow whitish arch formed at right angle at 9:45 p. m. When first observed the arch appeared to be made by or formed of small patches of cirrus clouds, which gradually formed into a well-defined arch spanning the sky from horizon to horizon; no apparent movement; arch plainly visible from 10 p. m. to 10:30 p. m., then gradually disappeared, becoming invisible by 10:45 p. m.

61. *Boise, Idaho* (105th mer.), August 26, 1916.—A singularly brilliant aurora was seen by people in the city from 9 p. m. to about midnight, but not observed by any of the regular station force. The arc was slightly colored, but the beams were white, at times reaching almost to the zenith.

62. *Seattle, Wash.* (120th mer.), August 26, 1916.—[Aurora reported. No details given.]

63. *Tacoma, Wash.* (120th mer.), August 26, 1916.—Aurora on the 26th. [No details.]

Other observations of the aurora of August 26.

Two further reports concerning this aurora gain interest from the southern latitude of the observers.

Warren, Albemarle County, Va. (lat. 37° 45′ N.; long. 78° 30′ W.)—There was nothing unusual between 8 and 9 p. m. (75th mer. time) on the night of August 26, but at 9:05 the sky became remarkably bright [low down and on my western horizon],[3] and had the appearance of dawn, for the sky became streaked with a pale yellow glow. From [a central point of this glow] a spear of light gradually lengthened and by 9:30 p. m. it had taken the appearance of a searchlight beam. Simultaneously red lights appeared and faded [on the northwestern horizon, reaching a short distance upward and extending perhaps 2 degrees horizontally, about reaching my meridian].

At 10:15 p. m. the shaft of yellow light was unusually brilliant and began to widen, until it was as broad as the Milky Way, which it crossed. This beam became vapory and filmlike as it broadened, but when it again narrowed at 10:25 it was intensified and resumed the shape of a searchlight beam. At 10:25 it began to fade rapidly and had completely vanished by 10:30 p. m.

I was informed by neighbors that at 1 [a. m. of the 27th] the red glow [on the horizon between northwest and north] reappeared and that it seemed to fade like mist, only to spring up once again in a half dozen places to glow for several minutes and fade away once more. This last display was said to be by far the most brilliant.—*J. Churchill Newcomb, Warren, Va.*

Nassawadox, Northampton Co., Va. (lat. 37° 30′ N., long. 75° 50′ W.).—Saturday evening, August 26, 191[illegible], from 8 to 10:30 p. m. the north and northeastern [northwestern?] sky was much lighter than the rest of the sky * * * [and] with a white light * * * with streaks of the white going far up into the heavens. It was in appearance like the rays of the sun, some streaks would fade away while others would come and gradually grow lighter until they began to fade. About 9:30 p. m. a white band from 1 to 1½ yards wide appeared across the heavens directly from west to east, going from one horizon to the other, and it was as even and direct a band as a piece of white muslin would have made.—*Mrs. Henry B. Baker, Nassawadox, Va.*

Alexandria Bay, N. Y. (lat. 44° 20′ N., long. 75° 55′ W.).—This aurora illuminated the sky, between the hours of 8 and 11 p. m. (75th mer. time) in a wide area stretching from east to west, therefore bringing its center immediately overhead or in the zenith, a rather unusual feature in this section. The display consisted of irregular patches and short streamers of yellowish light of no great intensity but very rapid movement, the waves coming from the west * * *.

I feel more than ever convinced that the shapes of the cirrus clouds, especially those of the "mares' tails" variety, are in some way controlled or influenced by the forces producing the aurora. In my careful study of the short streamers and areas of light immediately overhead, to which I gave the closest attention, there was seemingly every evidence of this control. At times these areas would take on the exact form of the twisted plumes and combed-out cirrus, so much so that for a very few moments one would wonder if it were not cirrus that he was gazing at; but in a second or two this [appearance] would die out, leaving the black, starlit sky.

It was also clear, from watching the streamers right overhead, that a great deal of [their] uniformity was due to perspective, for in the area [overhead] they lost their pencil or searchlight effect, but nearer the horizon it was gained again * * *.—*Douglas Manning, Alexandria Bay, N. Y.*

York, N. Y. (lat. 42° 52′ N.; long. 77° 53′ W.).—Streamers, rising over half way to the zenith, were noticed about 8 p. m. (75th mer. time). The sky was partly clouded, especially in the north. As a background to the clouds, the aurora lit up the whole north with a curtain of white light. An arch about 15° in height, with its center west of north, was seen as soon as the clouds moved away. At 8:10 a bright spot, perhaps 10° in diameter, was seen nearly due south at an altitude of approximately 35°; it moved slowly westward and was hidden under clouds moving from west-northwest. A few minutes later luminous, cloud-like streamers were noticed in the east. These moved southward and depended, like fracto-nimbus clouds, from the lower side of a Ci-Cu. band extending across the northeast. By 8:45 the arch in the north had nearly doubled in height, while pulsating streamers from northeast to west reached two-thirds of the way to the zenith. Silent lightning was seen at intervals in the south and southeast from 8 to 8:40.

At 9:40 p. m. the aurora was the brightest. Streamers from west to east-northeast met about an open, dark space southeast of the zenith. Before their greatest height was attained light rolled up in waves and at other times like the rays of a searchlight. Soon after the corona was formed the streamers died away and had disappeared by 10 p. m. Clouds, unnoticed during the illumination, then covered the whole sky; their direction appeared to be from the southwest. The temperature was 74° at 6 p. m. The barometer remained steady during the night at 29.22 inches (uncorrected). Rain began in the night and continued at intervals till 11:30 a. m. of the 27th, 0.28 inch falling.—*Milroy N. Stewart, York, N. Y.*

[3] Remarks in [ ] are added from a rough diagram submitted by our correspondent but not reproduced.—C. A., Jr.

Aurora of August 26, 1916, at Bristol, England.[4]

A fine exhibition of aurora borealis was observed by Mr. W. F. Denning at Bristol [lat. 51° 27′ N., long. 2° 35′ W., approx.] in the early morning of Sunday August 27, between the hours of 2 and 4 G. M. T. [i e. between 9 and 11 p. m., Saturday, August 26, 75th meridian Time]. Shafts of light were first observed at about $2^h\ 15^m$ [$9^h\ 15^m$ p. m., Aug. 26, 75th m. t.] ascending among the stars of Ursa Major and Draco, and reaching considerable altitudes. Changes affected the appearances at short intervals, the streamers would fade away and new ones form, while the invariable disposition of the whole was to move quickly from the west to the east side of the north point. Some of the more conspicuous streamers were particularly recorded as they passed over certain stars, and the mean rate of motion across Ursa Major was found to be 15° in three minutes.

The active region seemed to extend from as nearly as possible NW. to NE., but the NW. and N. showed the greatest abundance of streamers; in the NNE. there was a succession of faint bands of light rising upward to the left of Auriga. Many of the rays observed in the N. region could be faintly traced to altitudes of 70°. The phenomenon was watched until $3^h\ 45^m$ [$10^h\ 45^m$ p. m., Aug. 26, 75th m. t.], when the sky had regained its normal appearance, and twilight had become strong in the northeast.

[4] "Nature," London, Aug. 31, 1916, No. 2444, 97:551.

OTHER AURORAS DURING AUGUST, 1916.

The following extracts from the August, 1916, journals of Weather Bureau stations show where and when auroras were observed in the United States between August 1 and 25, inclusive, and on the 28th and 29th:

Auroras of August 1 to 25.

Ludington, Mich. (90th mer.), August 1, 1916.—An aurora was observed at 11:30 p. m. Its beginning was not observed. It probably continued to midnight or later. The display consisted of a long, low, whitish arch with altitude of the summit about 20° and azimuth 135° to 225°.

Houghton, Mich. (90th mer.), August 2, 1916.—Aurora observed to-night, but was not noteworthy.

Bismarck, N. Dak. (90th mer.), August 2, 1916.—Aurora observed at 10:30 p. m. [No data given.]

Alpena, Mich. (90th mer.), August 5, 1916.—Aurora observed; only an ill-defined glow of light along the northern horizon.

August 19, 1916.—The aurora when first observed at 7:50 p. m. consisted of an arch above the northern horizon, 20° altitude, azimuth 125° to 235°. Streamers, which varied constantly and rose to 40° altitude, developed at 9:20 p. m. By 9:30 p. m. the arch had broken up. Isolated streamers were observed at intervals until late at night.

Duluth, Minn. (90th mer.), August 19, 1916.—Rather brilliant aurora, azimuth 215° to about 250°, observed from 9 p. m. to some time after 10 p. m. Its color was the usual greenish-white with bright perpendicular shafts that reached an altitude of about 45°.

Devils Lake, Wis. (90th mer.), August 19, 1916.—Auroral display recorded on the 19th was small, the arch being about 18° in altitude and its azimuth, from 140° to 170°. Underneath the arch was darkness, while above there was considerable light of pale greenish color. No long streamers or bands of light were observed. The display was observed at 10:30 p. m.

Grand Forks, N. Dak. (90th mer.), August 20, 1916.—Aurora on August 20. [No data given.]

Alpena, Mich. (90th mer.), August 22, 1916.—Aurora observed; only an ill-defined glow along the northern horizon.

Aurora of August 28, 1916.

The brilliant aurora of August 26–27 was followed by another unusually bright display on the night of the 28th; but the available reports at present scarcely justify the conclusion that the disturbance which began on the 26th was really continuous through into the night of the 28th and even the 29th (see Canton, N. Y., Aug. 29, below).

Boston, Mass. (75th mer.), August 28, 1916.—Aurora was reported to have occurred on the night of the 28th, but was not observed at the station by reason of artificial illumination in the city.

New Haven, Conn. (75th mer.), August 28, 1916.—Aurora borealis observed 10:45 p. m. to 11 p. m.; not bright; a glow on the northern horizon with faint rays or streamers little more than suggested at intervals.

Canton, N. Y. (75th mer.), August 28 ,1916.—Auroral arch north to northeast, 9 to 11:30 p. m. Altitude 15°. Occasional streamers, altitude 40° to 45°.

York, N. Y. (lat. 42° 52′ N.; long. 77° 53′ W.; 75th mer.), August 28, 1916.—Arch and streamers first noticed about 10 p. m. Streamers did not last long, but arch remained for more than an hour. At 10:25 p. m. several parallel, luminous bands, about 15° in height, were seen above Ursa Major. They appeared perpendicular to a line joining the stars Benetnasch and Alcor, and extended eastward as far as the Milky Way. The bases of these bands were about half way from the horizon to the zenith; their width increased somewhat toward the east. At irregular intervals part of the arch on the horizon would become brighter; this luminous spot would move westward; then the parallel bands, which, perhaps, had almost disappeared, would shine with renewed brillance and continue to do so after the arch had resumed its steady glow. At no time were these bands connected with the arch, nor did they greatly increase their length toward the zenith. They were last noted at 11:15, after which they gradually faded out—the arch remaining till after 11:40. Barometer 29.44 (uncorrected); temperature 65°. No rain followed.—*Milroy N. Stewart, cooperative observer.*

Alpena, Mich. (90th mer.), August 28, 1916.—Aurora observed; only an illdefined glow of light along the northern horizon.

Ludington, Mich. (90th mer.), August 28, 1916.—Aurora from about 8:15 p. m. to about midnight. A broken arch, with altitude of summit 25° to 30°, and azimuth 150° to 210°, was present from 8:30 p. m. to 9 p. m. There were some streamers with it. Between 9 and 10 o'clock there were two arches, about 10° apart with a dark band between them. The altitude of the outer arch was 30° and the azimuth 145° to 235°. Streamers radiated upward from it. There was some flashing at 10 p. m.

Escanaba, Mich. (90th mer.), August 28, 1916.—An auroral display was observed at 8:20 p. m. The phenomenon consisted of a well-defined arch of about 10° in altitude and about 140° to 220° in azimuth across the northern horizon. A few varying and occasional streamers were observed, none reaching an altitude of more than 60°. The light was of a greenish tint. The phenomenon continued quite late, when it was reported the streamers, one in particular, became very bright. It was not under the observation of the observer after about 9 p. m.

Houghton, Mich. (90th mer.), August 28, 1916.—Aurora was observed to-night but was not noteworthy.

Duluth, Minn. (90th mer.), August 28, 1916.—Very brilliant aurora observed between 9 and 10 p. m., azimuth 110° to 230°. Altitude of highest greenish-white shafts of light about 60°. At 9:25 p. m. there was a shaft of bright light about 5° wide at the widest portion and extending from near the horizon at azimuth 248° across the zenith to about the horizon at azimuth 68.

Huron, S. Dak. (90th mer.), August 28, 1916.—[During the late evening an auroral glow was observed in the north.]

Bismarck (90th mer.), August 28, 1916.—Faint aurora observed at 9:30 p. m.

Williston (90th mer.), August 28, 1916.—An aurora was observed from 9:20 p. m. to 10:25 p. m., extending in azimuth from 160° to 225°; a faint arch was first seen resting upon a dark segment, which rose to an altitude of about 15°; at intervals a few streamers of a dull whitish color appeared, some of which reached an altitude of about 30°; the dark segment began to disappear about 10:05 p. m., and by 10:25 the aurora was no longer visible.

Aurora of August 29, 1916.

Canton, N. Y. (75th mer.), August 29, 1916.—Faint auroral arch, altitude 12°, observed 10 p. m.

SECTION II.—GENERAL METEOROLOGY.

DISTRIBUTION OF PRECIPITATION IN CHINA DURING THE TYPHOONS OF THE SUMMER OF 1911.

By CO-CHING CHU, A. M.

[Dated: Cambridge, Mass., June 22, 1916.]

In connection with a study of rainfall distribution in China, the writer studied the typhoons of the summer of 1911, using the data published in the latest report of the Zi-ka-wei Observatory. Of the 17 typhoons that occurred during that summer from June to September, inclusive, only 7 crossed the coast of China. Four of these seven will be discussed here. Their trajectories are sufficiently different from one another to indicate that they belong to different classes or types, but at present no attempt will be made to classify them. When drawing the maps of the accompanying precipitation, it is difficult to determine to which storm the precipitation belongs when two storms succeed each other closely. Owing to the scarcity of rainfall data for China, it is out of the question to undertake so thorough a discussion as Mr. Torahiko Terada[1] has given in his articles "The distribution of cyclonic precipitation in Japan." The individual rainfalls for each storm are given in Tables 1 and 2.

The following four rainfall-distribution maps of China are based upon the data contained in "Bulletin des Observations, 1911," of the Zi-ka-wei Observatory (Zi-ka-wei, 1915). On the fourth map (fig. 7) the rainfall data for the Japanese and the Philippine Islands are from other sources.[2] The storms are considered in the order of their complexity, the simplest first, and not in their chronological order of occurrence.

Typhoon of August 8–15, 1911. (No. 66.)

This storm (storm No. 66)[3] caused heavy precipitation in Manchuria and central China, resulting in disastrous floods in the latter region. Several particulars should be mentioned in connection with this storm. The area of precipitation is quite symmetrical with respect to the storm track, and the intensity of rain decreases from the low center. The two areas of heavy rainfall, 100 mm. (3.9 in.) or more, are both situated at the places where the storm passed from ocean to land, one at the mouth of the Yangtze and the other near Newchwang. In Newchwang, where the average annual fall (for the period 1901–1911) amounts to only 638.2 mm. (25.1 in.), there was on August 13 a precipitation of 201 mm. (7.9 in.), or more than 30 per cent of the average yearly total.

Southern China did not receive any rainfall, probably owing to the fact that the trajectory of the storm was well to the north. The storm traveled a little slower on the continent than on the ocean.

The typhoon of September 24–October 11, 1911. (No. 76.)

In contrast with the preceding storm, this storm affected southern China but not northern China or Manchuria. The storm divided north of Luzon, one portion going to Formosa and the other to Kwangtung (fig. 4.) So far as rainfall is concerned the latter branch is practically of no importance. The movement of the first branch was greatly retarded on entering Formosa. Between August 3 and 6 the storm center could not be located; its progress as shown on the map was very slow on these three days.

The rainfall distribution is uniform, as in the preceding storm, the heaviest precipitation occurring near the center of the storm. All of the rain fell in the period October 1–4, and most of it between the 1st to 3d, preceding the apparent stoppage of the storm center. There was no precipitation in northern China and practically no rain west of the line drawn between Hankow and Pakhoi.

The typhoon of June 28–July 8, 1911. (No. 55.)

This is chronologically the first typhoon of the year 1911 that is of any importance. The long trajectory of the storm (fig. 6) on the continent made the rainfall area more extensive than in the two preceding storms (fig. 5). Although the storm went far inland, the heavy precipitation occurred on the coast and at a distance from the center, except on the southern coast where the storm passed from sea to land. The distribution of rainfall is irregular and patchy. On the whole, however, the isohyets can be said to run parallel to the path of the storm. The velocity of the storm did not perceptibly diminish on land compared with its velocity at sea.

The typhoon of July 12–21, 1911. (No. 59.)

This storm is remarkable for its heavy rainfall in northern and central Luzon, P. I. (See fig. 7.) The precipitation at Baguio for the period July 14–17, 1911, amounted to 2,238.7 mm. (88.14 inches).[4] From noon of July 14 to noon of the 15th the amount of precipitation, according to the Friez quadruple register at that station, was 1,168 mm. (45.98 inches), the heaviest 24-hour rainfall yet on record in any part of the world.[5]

The precipitation in Formosa and China did not approach that of Luzon in intensity, but it covered a considerable area on the continent. The area of heaviest precipitation in Formosa occurred at the extreme south, where the storm center passed. Rainfalls of more than 400 mm. (16 inches) were recorded at Hunchen and Taitung. In China also the heaviest precipitation occurred on the coast where the LOW passed from sea to land (fig. 8). The two areas of heavy rainfall are located, one on the central Chinese coast and the other in southern Manchuria, almost on the same region where the heavy precipitation occurred in storm No. 66. The rainfall distribution on the continent is uniform, on the whole the trend of isohyets following the storm path. The southern coast of China had no precipitation throughout the period.

In Japan the uniformity of rainfall distribution is striking. There was no precipitation in Kiushu, Shukoku, southern part of Honshu, or the northern part of Yezo. The rainfall area had the shape of a semicircle, with the heaviest rainfall at the center, near Akita.

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[1] See author's abstract in MONTHLY WEATHER REVIEW, March, 1916, 44: 127–128.

[2] Data for stations in Japan, Korea, and Formosa are from Jour. Metl. soc., Japan, September, 1911, pp. 21–24.
Data for stations in the Philippines are from Bull. Manila Central Observatory, Philippine Weather Bureau, July, 1911, pl. 4.

[3] The storm numbers are the original reference numbers assigned them in the Zi-ka-wei report. They are here retained for the convenience of future reference.

[4] Bulletin, Manila central observatory, July, 1911, pl. 4.

[5] *McAdie, A. G.* Rainfall of California. Berkeley, Cal., 1914. (Univ. Cal., Public. in geogr., v. 1, no. 4.) p. 171.

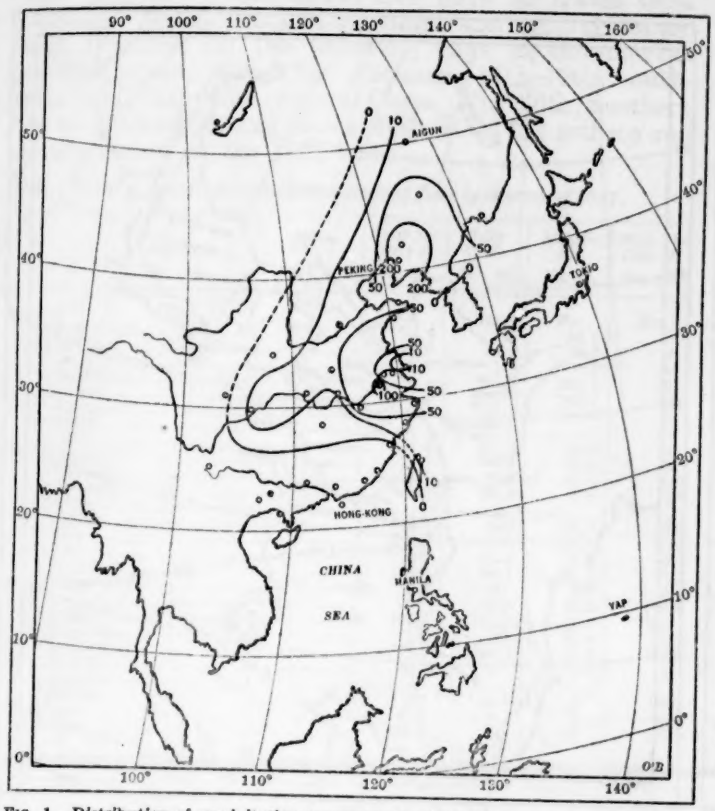

FIG. 1.—Distribution of precipitation accompanying the typhoon of August 8-15, 1911. (Storm No. 66.)

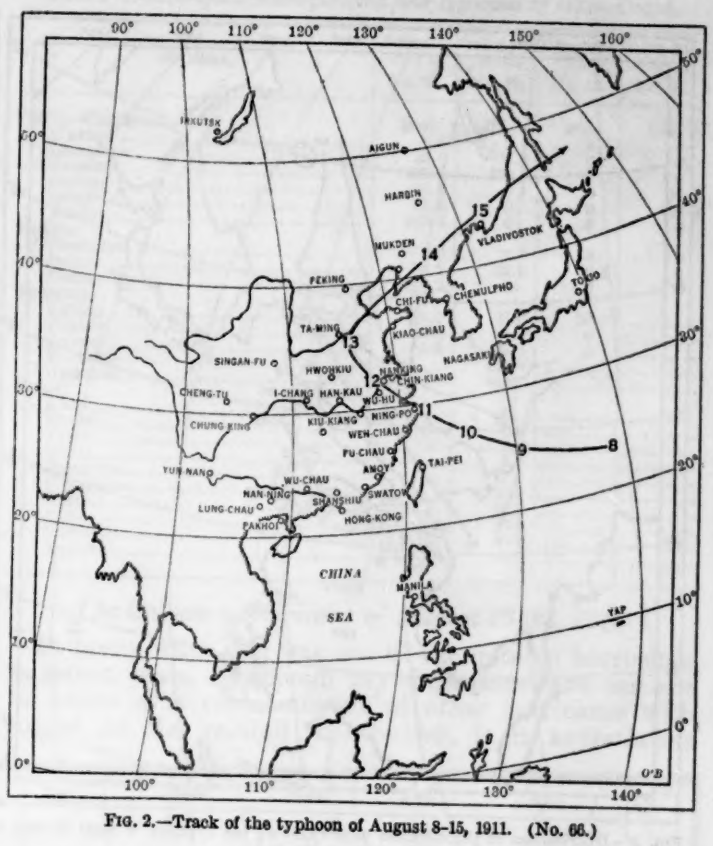

FIG. 2.—Track of the typhoon of August 8-15, 1911. (No. 66.)

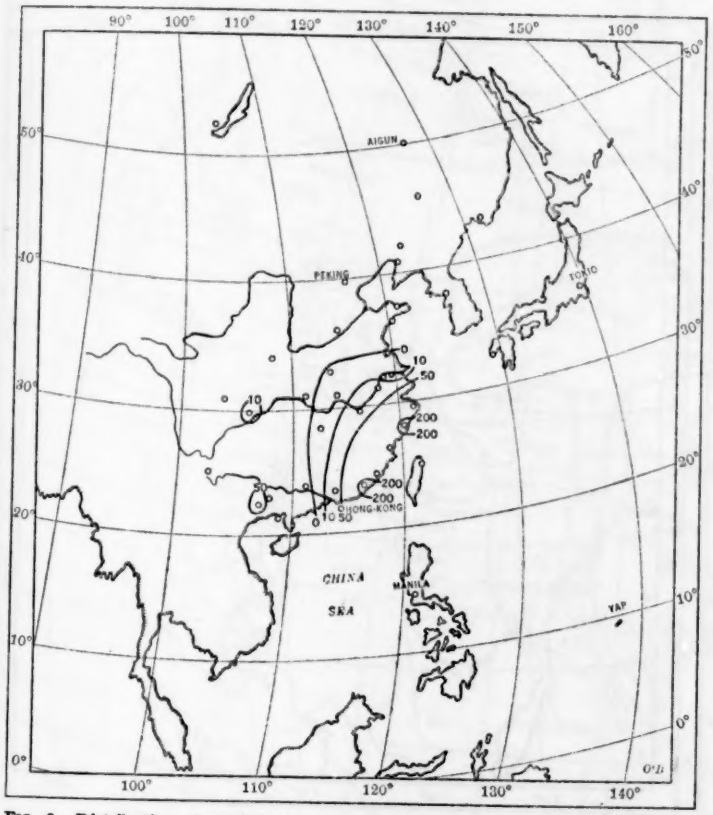

FIG. 3.—Distribution of precipitation accompanying the typhoon of September 24-October 11, 1911. (Storm No. 76.)

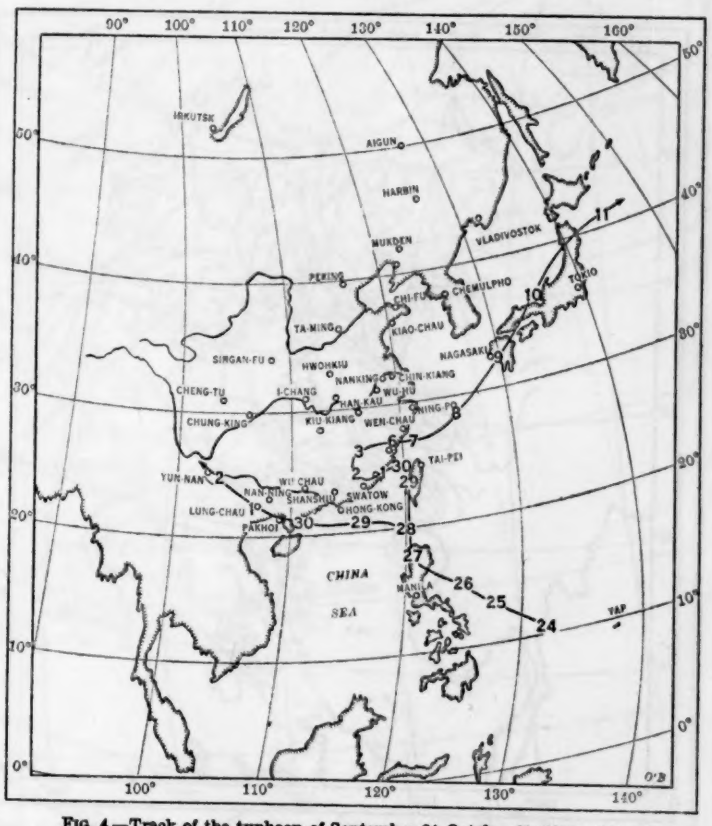

FIG. 4.—Track of the typhoon of September 24-October 11, 1911. (No. 76.)

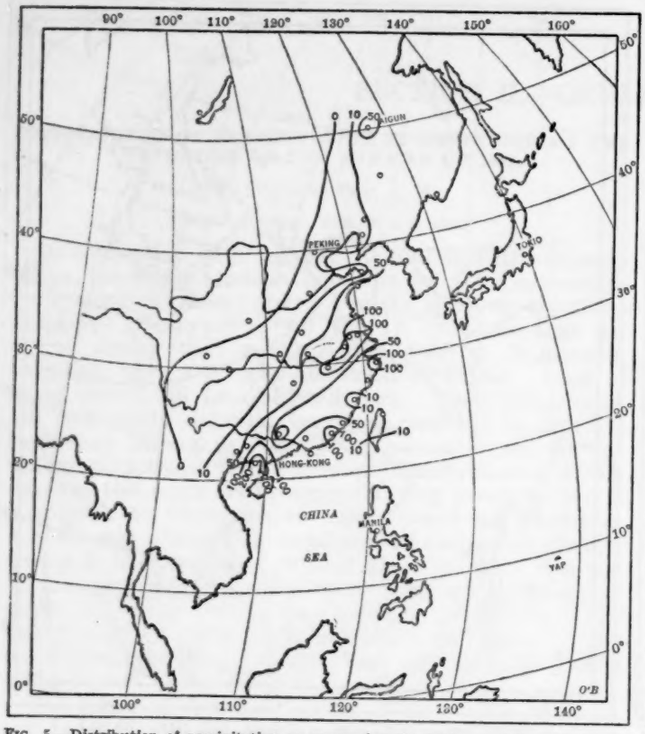

FIG. 5.—Distribution of precipitation accompanying the typhoon of June 28–July 8, 1911. (Storm No. 55.)

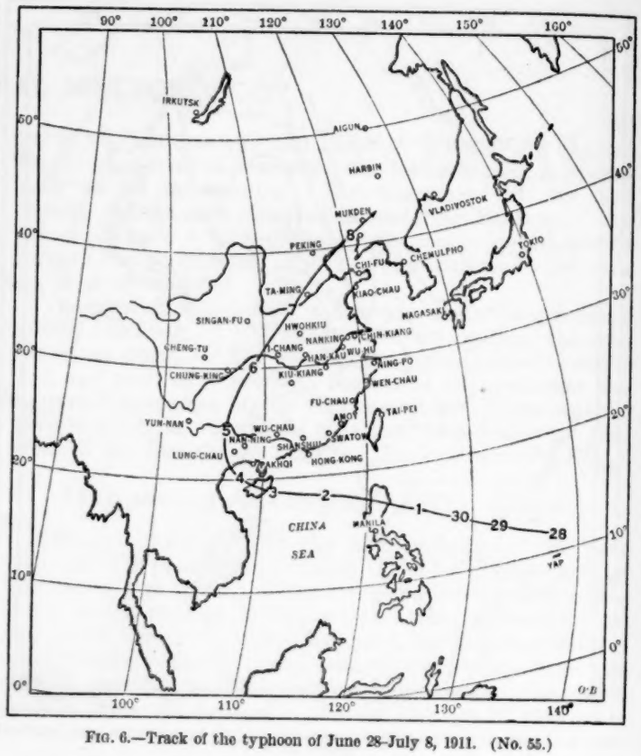

FIG. 6.—Track of the typhoon of June 28–July 8, 1911. (No. 55.)

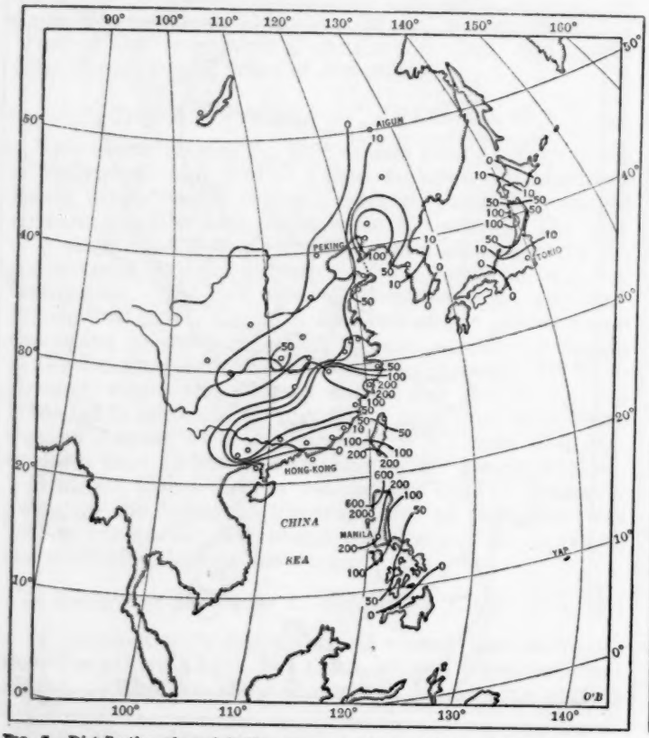

FIG. 7.—Distribution of precipitation accompanying the typhoon of July 12–21, 1911. (Storm No. 59.)

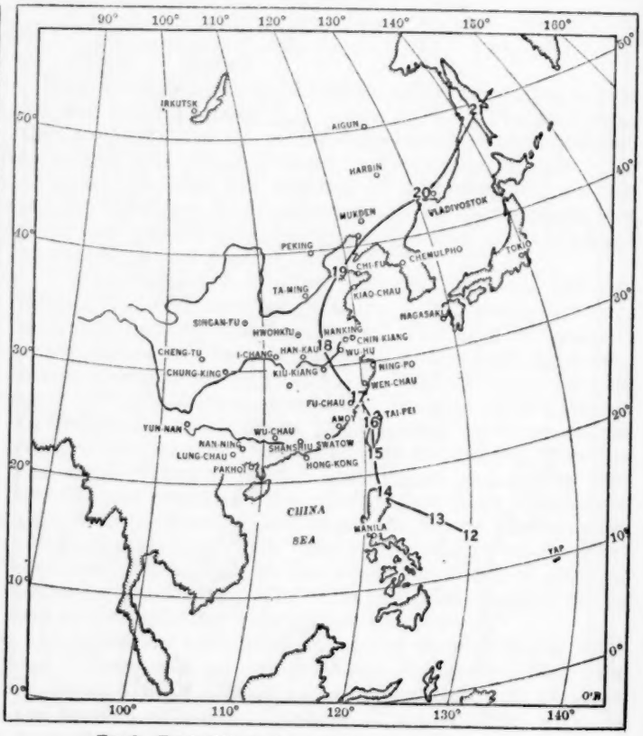

FIG. 8.—Track of the typhoon of July 12–21, 1911. (No. 59.)

It took the storm about five days to travel from Luzon to Manchuria and northern and central Japan. Rain occurred on the following days in the districts named: Luzon, 14th–17th; Formosa, 15th–19th; southern China, 15th–20th; central China, 17th–20th; northern China, Manchuria, and Korea, 18th–20th; in northern and central Japan on the 19th–22d.

TABLE 1.—*Rainfalls accompanying four typhoons of 1911.*

Stations.	June 28–July 8. No. 55.	July 12–21. No. 59.	Aug. 8–15. No. 66.	Sept. 24–Oct. 11. No. 76.
CHINA:	*Mm.*	*Mm.*	*Mm.*	*Mm.*
Aigun	54.8	9.7	18.5	0
Harbin	15.5	24.4	60.9	0
Vladivostok	4.0	1.5	9.0	0
Newchwang	5.4	102.3	357.1	0
Mukden	33.9	112.6	261.7	0
Tientsin	17.4	7.3	14.6	0
Taming	.....	.....	.....	0
Chefoo	2.5	37.0	42.9	0
Tsingtau	77.7	95.3	50.4	0
Hwohkiu	26.0	4.5	60.3	0.6
Chenkiang	135.9	30.2	7.4	6.6
Chengtu	.....	.....	.....	.....
Nanking	149.5	9.9	34.6	12.2
Wuhu	48.7	4.3	134.6	23.3
Ichang	8.9	55.1	18.8	0
Shanghai	42.8	14.3	30.5	57.2
Hankow	70.6	0	1.3	0
Ningpo	0	17.0	50.0	48.9
Kinkiang	107.5	138.0	77.2	24.1
Chungking	1.0	1.5	41.4	10.1
Wenchow	13.3	254.4	10.5	249.6
Changsha	29.2	0	1.0	1.3
Yunnanfu	.....	.....	.....	.....
Foochow	7.6	80.2	0	60.5
Amoy	42.2	5.1	0	85.3
Swatow	180.8	6.8	0	322.4
Wuchow	3.6	2.0	0	0
Lungchow	50.0	77.3	0	0
Nanning	186.0	172.6	0	0
Shanshu	37.8	0	0	10.9
Hongkong	85.0	0	0	109.4
Pakhoi	239.8	0	0	0
KOREA:				
Chemulpo	3.0	2.5	0	0
Jensan	35.0	22.0	6.5	0
Fusan	207.2	0	0	0
FORMOSA:				
Ke'lung	11.0	23.0	39.0	.....
Taichu	42.0	84.0	0	.....
Tainan	5.0	170.0	0	.....
Taitung	.....	417.0	.....	.....
Hunchen	.....	441.0	.....	.....
JAPAN:				
Kobe	.....	0	.....	.....
Kyoto	.....	1.0	.....	.....
Fukui	.....	.....	.....	.....
Tokio	.....	3.0	.....	.....
Takuyama	.....	47.0	.....	.....
Fukushima	.....	28.0	.....	.....
Nagano	.....	52.0	.....	.....
Akita	.....	12.0	.....	.....
Hakodate	.....	36.0	.....	.....
Sapporo	.....	9.0	.....	.....

The Galveston hurricane of August 13–23, 1915.

In many ways this was one of the notable hurricanes in recent years. Although any single hurricane can not be taken as a representative of other hurricanes with regard to the rainfall distribution, it is nevertheless

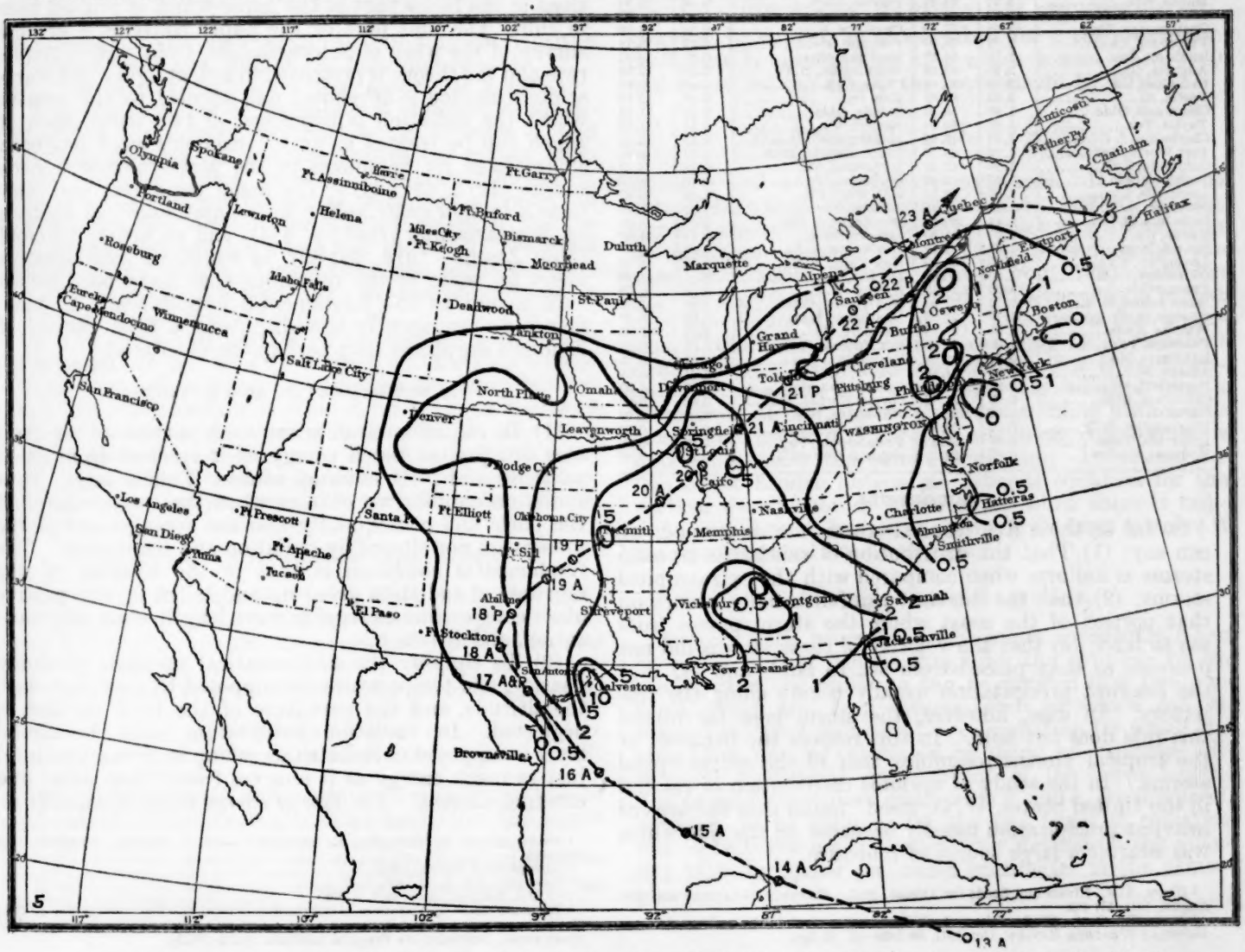

FIG 9.—Distribution of precipitation and the track of the Galveston hurricane of August 13–23, 1915. [The track has been corrected from unpublished data.]

interesting to compare the rainfall distribution map (fig. 9) of this storm with the maps of the four typhoons just discussed. Prof. A. J. Henry [6] has pointed out in connection with this storm that the distribution of rainfall in a tropical storm is different from that in an extratropical storm. In the latter the rain is not distributed so uniformly about the center as in the former. This storm, he continued, maintained its tropical character until it reached the upper Ohio Valley. The heavy rainfall in Galveston and Houston should be noted (see Table 2), as these stations are on the coast where the storm passed from sea to land. In this connection it might be mentioned that during the New Orleans hurricane of September 29, 1915, New Orleans had a precipitation of about 209 mm. (8.26 inches) within 24 hours on September 29.

TABLE 2.—*Amount of rainfall received during the Galveston hurricane of Aug. 13–23, 1915.*

Place.	Amount.		Place.	Amount.	
	Ins.	*Mm.*		*Ins.*	*Mm.*
Galveston, Tex.	15.87	403.10	Staunton, Va.	0.74	18.80
Houston, Tex.	9.12	231.65	Buffalo, N. Y.	0.74	18.80
St. Louis, Mo.	8.18	207.77	Parkersburg, W. Va.	0.70	17.78
Evansville, Ind.	5.60	142.24	Kansas City, Kans.	0.70	17.78
Fort Smith, Ark.	5.98	151.89	Hartford, Conn.	0.68	17.27
Springfield, Ill.	4.60	116.84	Pueblo, Colo.	0.66	16.76
Memphis, Tenn.	4.90	124.46	Omaha, Nebr.	0.65	16.51
Shreveport, La.	4.82	122.43	North Platte, Nebr.	0.64	16.26
Nashville, Tenn.	4.54	115.32	Wytheville, Tenn.	0.68	17.27
New Orleans, La.	4.64	117.86	Montgomery, Ala.	0.66	16.76
Harrisburg, Pa.	4.38	111.25	Tampa, Fla.	0.62	15.75
Burwood, La.	3.88	98.55	Asheville, N. C.	0.62	15.75
Atlanta, Ga.	3.42	86.87	Lynchburg, Va.	0.61	15.49
Cairo, Ill.	3.34	84.84	Cleveland, Ohio	0.64	16.26
Mobile, Ala.	3.34	84.84	Detroit, Mich.	0.60	15.24
Canton, N. Y.	3.30	83.82	Sioux City, Iowa	0.56	14.22
Chattanooga, Tenn.	2.98	75.69	Charlotte, N. C.	0.54	13.72
Vicksburg, La.	2.79	70.87	Portland, Me.	0.52	13.21
Scranton, Pa.	2.18	55.37	Meridian, Miss.	0.51	12.95
Augusta, Ga.	2.56	65.02	Wilmington, N. C.	0.48	12.19
Savannah, Ga.	2.09	53.09	Chicago, Ill.	0.48	12.19
Peoria, Ill.	2.05	52.07	Erie Pa.	0.48	12.19
Cincinnati, Ohio.	1.98	50.29	Toledo, Ohio.	0.44	11.18
Taylor, Tex.	1.97	50.04	Norfolk, Va.	0.44	11.18
Charleston, S. C.	1.93	49.02	Jacksonville, Fla.	0.41	10.41
Fort Worth, Tex.	1.92	48.77	Grand Rapids, Mich.	0.34	8.64
Columbia, S. C.	1.86	47.24	Richmond, Va.	0.32	8.13
Pensacola, Fla.	1.67	42.42	Cheyenne, Wyo.	0.26	6.60
Louisville, Ky.	1.66	42.16	Key West, Fla.	0.25	6.35
Syracuse, N. Y.	1.49	37.85	Abilene, Tex.	0.21	5.33
Indianapolis, Ind.	1.44	36.58	Birmingham, Ala.	0.20	5.08
Macon, Ga.	1.37	34.80	Lincoln, Nebr.	0.18	4.57
Boston, Mass.	1.32	33.53	Des Moines, Iowa.	0.18	4.57
Lexington, Ky.	1.22	30.99	New York, N. Y.	0.16	4.06
Oklahoma, Okla.	1.20	30.48	Del Rio, Tex.	0.11	2.79
Thomasville, Ga.	1.20	30.48	Raleigh, N. C.	0.06	1.52
Block Island, R. I.	1.10	27.94	New Haven, Conn.	0.05	1.27
Oswego, N. Y.	1.10	27.94	Nantucket, Mass.	0.05	1.27
Wichita, Kans.	1.08	27.43	Eastport, Me.	0.04	1.02
Palestine, Tex.	1.06	26.92	San Antonio, Tex.	0.03	0.76
Baltimore, Md.	0.97	24.64	Dodge City, Kans.	0.01	0.25
Albany, N. Y.	0.96	24.38	Denver, Colo.	0.01	0.25
Northfield, Vt.	0.96	24.38	Quebec, Ontario	0.00	0.00
Columbus, Ohio.	0.93	23.62	Corpus Christi, Tex.	0.00	0.00
Hatteras, N. C.	0.92	23.37	Milwaukee, Wis.	0.00	0.00
Binghamton, N. Y.	0.92	23.37	Alpena, Mich.	0.00	0.00
Knoxville, Tenn.	0.88	22.35	Philadelphia, Pa.	0.00	0.00
Montreal, Quebec	0.88	22.35	Atlantic City, N. J.	0.00	0.00

Conclusions.

So far as these five tropical storms are concerned, we can say: (1) That the distribution of rainfall in tropical storms is uniform when compared with the extratropical storms; (2) that the heaviest rainfall usually occurs on that portion of the coast where the storm passes from sea to land; (3) that the velocity of these storms did not decrease as they passed from sea to land; and (4) that the heaviest precipitation usually occurs along the trajectory. In case, however, the storm goes far inland this rule does not hold. In this respect the behavior of the tropical storms resembles that of the extratropical storms. In the study of cyclonic distribution of rainfall in the United States, W. G. Reed [7] found that the area of heaviest precipitation usually occurred on the side which was nearest a large source of moisture.

[6] *Henry, A. J.*, Rivers and floods for August, 1915. MONTHLY WEATHER REVIEW, August, 1915, 43: 413.

[7] *Reed, Wm. Gard.* Study of the cyclonic distribution of rainfall in the United States. MONTHLY WEATHER REVIEW, Oct. 1911, 39: 1609–15. 11 figs.

RADIATION EQUILIBRIUM AND ATMOSPHERIC RADIATION.[1]

BY R. EMDEN.

(Abstract and translation by H. BATEMAN, Govans, Md., Aug. 14, 1916.)

1. INTRODUCTION.

Much attention is being paid in the United States to the study of atmospheric radiation and many valuable investigations have been carried out by American meteorologists. These workers have also shown a kindly interest in the researches of European scientists, and as a proof of this the Smithsonian Institution has recently published the admirable work of Anders Ångström in its Miscellaneous Collections (v. 65, no. 3, 1915). An important advance in the theory of atmospheric radiation was made about seven or eight years ago when W. J. Humphreys [2] and E. Gold [3] showed that the sudden decrease of the vertical temperature gradient to a very low value, which is indicated when a balloon rises above the convective region, can be profitably studied in connection with the theory of radiation equilibrium. In Emden's paper the study of this relation is carried further, Humphreys's formula for the temperature of the isothermal region is obtained in another way and Gold's mathematical investigations are repeated and developed under slightly different assumptions. Some of the theoretical results closely resemble those obtained by Gold and are summarized with other interesting conclusions in the latter part of the paper which is printed here in full. The first part of the paper contains a critical survey of the work of Schwarzschild, Gold, and Humphreys and the theory is presented in a clear light. Schwarzschild's method is developed and applied to the case in which the radiation is composed of two parts, each of which can be treated as gray. Emden's work has been summarized by Schmauss in the Meteorologische Zeitschrift (1913, 48: 454). The same periodical also contains a further contribution to the mathematical analysis by Schwarzschild (Ibid., p. 454), and an article by Gold (Met. Ztschr., 1914, 49: 89), in which he expresses his views on some of the questions that have been raised with regard to the fundamental hypotheses. As some points are apparently still disputed,[4] a brief résumé of Emden's argument may perhaps be of interest.[5]

2. FUNDAMENTAL ASSUMPTIONS.

(1) In radiation equilibrium each particle of air radiates out just as much energy as it receives from other particles and from external sources if there any. Thus radiation equilibrium obtains when the temperatures of the parts and consequently also the arrangement of the masses are not altered by radiation and absorption. The fundamental condition is that of the equality of the amounts of radiation given up and taken in, irrespective of its composition as regards wave length, state of polarization, and direction.

(2) To simplify the mathematical problem, pressure, density, and temperature are supposed to vary only with the altitude, and the curvature of the level surfaces is neglected. In radiation equilibrium each horizontal layer is supposed to radiate (according to its temperature) just as much energy as it receives from other layers and external sources. *The flow of energy in an upward direc-*

[1] *Emden, Robert*, in Sitzungsb., K. bayerische Akad. d. Wissens., Munchen, 1913, 43:55–142.

[2] Astrophysical Journal (1909).

[3] Proc. Roy. Soc. A. 82, 1909, p. 43.

[4] Cf. Met. Zeitschr., May, 1914, 31:239.

[5] For more recent presentations of the theories of Gold and Humphreys see: *E. Gold.* The International Kite and Balloon Ascents, Geophysical Memoirs, No. 5 (1913). *W. J. Humphreys.* Journal of the Franklin Institute, March (1913).

tion across the layer is, however, not assumed to be equal to the flow of energy downward across the layer.

(3) *The absorption of diffuse radiation can be treated with sufficient exactness by an approximate theory in which diffuse radiation is replaced by parallel radiation and the absorption coefficient for each wave length is doubled.* More precisely, if a horizontal layer of air of mass dm is traversed by a quantity of radiation $S_\lambda \delta\lambda$ with wave lengths lying between λ and $\lambda+\delta\lambda$, the amount absorbed is $a_\lambda S_\lambda \delta\lambda$ for diffuse radiation and $\alpha\lambda S\delta\lambda$ for parallel vertical radiation where $a_\lambda = 2\alpha_\lambda$. The absorption coefficient α_λ is at first assumed to be independent of the pressure which obtains and to be a function only of the wave length λ, but this assumption is abandoned later. The absorption coefficient for diffuse radiation will be denoted by k_λ.

The italic sentences indicate the points in which Emden's hypotheses differ from those of Gold. In the treatment of diffuse radiation Gold endeavors to work with formal rigor. Unfortunately the absorption coefficients of air which come into consideration are not known with sufficient exactness and when values are adopted numerical results can only be obtained after careful mechanical quadratures. Gold also treats solar radiation, earth radiation, and atmospheric radiation separately in his equations and inequalities. In Emden's treatment the two former appear only in the boundary conditions.[6]

Emden adopts the view that the inexactness involved in assumption (3) is negligible compared with that due to our lack of knowledge of the absorption coefficients. To justify this he makes a calculation in which the curvature of rays passing through layers of air of different densities is disregarded [7] and obtains the following results:

1. For black radiation we have accurately $a_\lambda = 2\alpha_\lambda$.

2. If the intensity of the radiation increases in the direction of the masses traversed a_λ lies between α_λ and $2\alpha_\lambda$, if it decreases in the direction of the masses traversed, we have always $a_\lambda > 2\alpha_\lambda$. The variability of a_λ makes a rigorous mathematical treatment of radiation equilibrium very difficult, for a_λ is a function of the distribution of temperature which is to be found. We could calculate it by successive approximations, but in the cases which will be of importance the variation of temperature is such that a_λ is roughly equal to $2\alpha_\lambda$.

3. If a horizontal layer of air at constant temperature is bounded on one side by a black surface at the same temperature, then whatever radiation the layer receives from the black surface it gives it up again to the same amount and with the same wave-length. It thus finds itself in radiation equilibrium. Hence if the earth's surface radiates like a black body, an isothermal atmosphere at the same temperature can not alter the issuing radiation.

3. *Conditions for radiation equilibrium.*

Let E_λ be the emissivity of a black body for wavelength λ and let A_λ, B_λ, be the currents of energy of wavelength λ which cross the boundaries of a thin horizontal layer of mass dm per sq. cm. in the upward and downward directions, respectively, then we have the equations

$$B'_\lambda = k_\lambda E_\lambda - k_\lambda B_\lambda, \qquad (1)$$

$$A'_\lambda = k_\lambda A_\lambda - k_\lambda E_\lambda, \qquad (2)$$

where primes denote differentiations with respect to m and m is measured vertically downward from the upper limit of the atmosphere. For $m=0$ the boundary condition is $B_\lambda = \bar{B}_\lambda$, the amount furnished by the solar radiation (diminished by the albedo). At the lower boundary, $m=M$, we have $A_\lambda = \bar{A}_\lambda$, the amount furnished by the earth's radiation. In radiation equilibrium we have for each value of m

$$2\int_0^\infty k_\lambda E_\lambda d\lambda = \int_0^\infty k_\lambda (B_\lambda + A_\lambda)\, d\lambda, \qquad (3)$$

whence

$$\int_0^\infty (B_\lambda - A_\lambda)\, d\lambda = \text{constant},$$

and is equal to the difference $\bar{B}-\bar{A}$ between the amounts of energy flowing to and away from the atmosphere at its upper boundary, the so-called "heat balance" (Wärmebilanz).

Let us see under what circumstances an isothermal state can exist. Assuming that E_λ is independent of m we obtain on integration

$$A_\lambda = A_{0\lambda}\, e^{mk_\lambda} + E_\lambda, \qquad B_\lambda = B_{0\lambda}\, e^{-mk_\lambda} + E_\lambda,$$

where $A_{0\lambda}$ and $B_{0\lambda}$ are constants of integration but functions of λ. The condition for radiation equilibrium is that

$$\int_0^\infty (B_{0\lambda}\, e^{-mk_\lambda} - A_{0\lambda}\, e^{mk_\lambda})\, d\lambda = \text{constant}$$

for all values of m. Emden asserts that this equation can be satisfied only if $B_{0\lambda}=0$ and $A_{0\lambda}=0$. In this, however, he appears to be mistaken, for if the absorption coefficient k_λ is a function of λ which is zero when $\lambda=0$ and $\lambda=\infty$, we can satisfy the requirement by putting

$$A_{0\lambda} = u\,\frac{d}{d\lambda}(k_\lambda), \qquad B_{0\lambda} = v\,\frac{d}{d\lambda}(k_\lambda),$$

where u and v are arbitrary constants. It should be noticed that these expressions make $A_{0\lambda}$ and $B_{0\lambda}$ change sign as λ passes through a value for which k_λ is a maximum or minimum. Unless this is physically impossible the conclusion which Emden draws from the equations $A_{0\lambda}=0$, $B_{0\lambda}=0$, must be rejected. His conclusion is that $A_\lambda = B_\lambda = E_\lambda$ for all values of m. This means that a portion of the earth's atmosphere can only be in radiation equilibrium at a constant temperature T if it is illuminated from above and below with the radiation from a black body at temperature T; thus according to this conclusion an isothermal layer in radiation equilibrium is impossible under the actual conditions. Influenced by this result Emden obtains an integral equation for the vertical distribution of temperature when there is radiation equilibrium, but as he does not attempt to solve it the equation need not be given here.

4. *Simplification of the problem.*

As very little progress can be made apparently when k_λ varies with λ, Emden simplifies the problem by assuming that the radiation can be divided into two portions (short and long waves), each of which can be treated as "gray radiation," i. e., radiation for which the absorption can be calculated by using an "average absorption coefficient" independent of the wave length. The average absorption coefficients k_1 and k_2 are supposed, however, to be different for the two types of radiation and to be functions of m since they depend on the quantity of water vapor per cubic centimeter of the atmosphere.

[6] Emden uses differential equations while Gold uses integral equations, so that the boundary conditions are contained implicitly in his equations.

[7] He also assumes that the absorption coefficient is independent of the pressure. This assumption is not made in Gold's work.

Writing A and B for the energy currents flowing in the upward and downward directions, respectively, and E for the energy emitted per cubic centimeter by a black body at temperature T, Emden now writes

$$A=A_1+A_2, \qquad B=B_1+B_2, \qquad E=E_1+E_2$$

and adopts the equations

$$B'=k_1E_1+k_2E_2-k_1B_1-k_2B_2, \tag{1a}$$

$$A'=k_1A_1+k_2A_2-k_1E_1-k_2E_2, \tag{2a}$$

$$2(k_1E_1+k_2E_2)=k_1B_1+k_2B_2+k_1A_1+k_2A_2, \tag{3a}$$

as the analogues of (1), (2), and (3).

The absorption coefficients of each layer of air for each type of radiation are now assumed to be proportional to the water vapor content, and by using well-known empirical formulæ for the variation of density and humidity with the height Emden is led to adopt the expressions—

$$k_1=4b_1m^3=0.4m^3, \qquad k_2=4b_2m^3=9.2m^3.$$

Emden now neglects A_1 in comparison with A_2; k_1A_1, in comparison with k_2A_2; and E_1 in comparison with E_2. Then, assuming that for $m=0$, $B-A=0$, so that the 'heat balance' is zero, he obtains from the above relations and from $B'_1=-k_1B_1$

$$B=A=\sigma\left\{\frac{b_2+b_1}{2b_1}-\frac{b_2-b_1}{2b_1}\,e^{-b_1m^4}\right\} \tag{4}$$

$$E=\sigma\frac{b_1+b_2}{2b_1b_2}\left\{b_2-(b_2-b_1)\,e^{-b_1m^4}\right\} \tag{5}$$

where σ is the fourth part of the solar constant diminished by the albedo. Putting $E=sT^4$, $\sigma=s\tau^4$, where $\tau=254°$, the 'effective earth temperature,' we obtain the value of T. At a considerable height m is small and we have Emden's equation (86)

$$T=254°\left(\tfrac{1}{2}+\frac{b_1}{2b_2}\right)^{\frac{1}{4}}=254°\left(\tfrac{1}{2}+\frac{k_1}{2k_2}\right)^{\frac{1}{4}}.$$

Some values of T are given in Table 1.

TABLE 1.—*Values of T for various values of the ratio k_1/k_2.*

$\frac{k_1}{k_2}$	1	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{10}$	$\frac{1}{20}$	0
T.....	$\left\{\begin{matrix}254°A\\-19°C\end{matrix}\right.$	$\begin{matrix}238°A\\-35°C\end{matrix}$	$\begin{matrix}224°A\\-49°C\end{matrix}$	$\begin{matrix}219°A\\-54°C\end{matrix}$	$\begin{matrix}215.87°A\\-57.23°C\end{matrix}$	$\begin{matrix}213.7°A\\-59.3°C\end{matrix}$

The temperature $-57.23°$ C is called the "inversion temperature" and denoted by T_i. The value obtained for $\frac{k_1}{k_2}=0$ agrees with Humphreys' value. Above a certain level we may put $p=gm$ in (5) and we then find with the aid of the relations $dp=g\rho dz$, $p=g\rho RT$, that the temperature gradient is given by Emden's (90)

$$\frac{dT}{dz}=\frac{1}{R}\frac{T^4-T_i^4}{T^4} \tag{6}$$

For stability we must have

$$\frac{dT}{dz}<\frac{1}{R}\frac{\kappa-1}{\kappa},$$

where κ is the ratio of the specific heats= 7/5. If the atmosphere is in radiation equilibrium only those layers are stable for which

$$7T^4<5T_i^4 \text{ A. or } T<234.8°=-38.2°\text{C}.$$

The variation of temperature with height may be derived from (6) and Emden obtains the following results: The height h is measured in meters:

TABLE 2.—*Vertical temperature changes by (6).*

T.....	215.84°	216°	216.1°	216.2°	216.3°	220°	230°
$-\frac{dT}{dh}$.....	0	0.000081	0.00014	0.00021	0.00029	0.00249	0.00765
h.....	00	11500	10530	9960	9540	5830	3770
T.....	234.82°	240°	250°	260°	270°	280°	288.8° A
$-\frac{dT}{dh}$.....	0.0098	0.0118	0.0152	0.0178	0.0202	0.0221	0.0235
h.....	3130	2730	1990	1380	860	386	0

Emden also calculates from equations (4) and (5) that the temperature of the lowest atmospheric layer is 15.8°C and that the temperature of the ground is 36°C. The discontinuity in temperature of 20 degrees is in reality greatly diminished by conduction of heat and evaporation. The remainder of the paper is now given in full.

5. *Summary.*

Let us consider briefly the foundations and results of the theory that has just been developed. If the radiation coming from the sun and amounting to 2 gram. cal./cm². min. were distributed uniformly over the surface of the solid earth deprived of its atmosphere, then on the assumption of gray radiation the earth would, independently of its emission (absorption capacity) set itself at the temperature of radiation equilibrium, viz, $T=285°=12°$C. Taking into account the albedo of the earth, the inflow of radiation is diminished by 37 per cent, consequently this temperature is lowered to $T=254°=-19°$C. We call this temperature the *effective earth temperature*. If now we cover the earth with an arbitrary atmosphere, then whether its layers are arbitrarily poor or rich in water vapor and absorb weakly or strongly, it will set itself in radiation equilibrium, with its lower part isothermal, at the effective earth temperature $T=254°=-19°$C (in agreement with Gold), provided the radiation is gray, i. e., provided the absorption capacity is assumed to be the same arbitrary quantity for all wave-lengths. If we examine the behavior for separate wave-lengths, we are led to an integral equation which can not be dealt with on account of the lack of the necessary physical data. We have consequently adopted an intermediary method in which the short-wave radiation of the sun and the long-wave counter radiation of the earth are each assumed to constitute gray radiation but with different absorption coefficients. The absorption (emission) of each atmospheric layer is put proportional to its water-vapor content; it is small for the incident short-wave radiation, large for the returning long-wave radiation; only when the water-vapor content is very small do they approach a common very small value. On this basis the following result was obtained:

Above a certain level the incident radiation is only weakened a little and the temperature of radiation equilibrium for each layer is determined solely by the ratio in which its content of water vapor absorbs short-waved and long-waved radiation, independently of the absolute values. When this ratio is zero we obtain the minimum temperature at which radiation equilibrium can occur, viz., $2\frac{1}{4}$ times smaller than the effective earth temperature, or 213.7° (−59.3°C.). For average humidity conditions we must diminish this ratio by $\frac{1}{2^{\frac{1}{3}}}$ giving a temperature of −57° C.; the value $\frac{1}{10}$ would give −54°C. These are the known temperatures of the stratosphere. In ascending the ratio $\frac{k_1}{k_2}$ increases with decreasing water-vapor content, the temperatures rise attaining the effective earth temperature for $\frac{k_1}{k_2}=1$. If the highest layers of the atmosphere are, as is to be expected, sufficiently poor in water vapor, then in spite of wide-spread ideas to the contrary, they are not characterized by very low temperatures, but find themselves throughout at temperature −19°C. At this temperature the atmosphere passes isothermally with increasing attenuation, through conditions which on account of the lack of physical data we are not able to deal with more closely, into the so-called empty space. If, on the other hand, we go downward, the temperatures likewise increase with increasing absorption. Since now, however, the absolute values of the absorption capacities of water vapor for short waves and long waves come into action, the calculated temperatures are essentially uncertain. Nevertheless we are able to calculate the temperature of the ground layer of the atmosphere as 15.8°C., agreeing well with observation. The important result was thereby obtained that from a level of about 3,000m. downward the atmosphere is mechanically unstable in radiation equilibrium. Convection will invalidate the calculated temperatures, but the temperature above this region and the temperatures of the ground layers will vary very little.

Now it is known that the atmosphere below an average height of about 10km. is almost always traversed vertically by the convection currents of long cycles, the characteristic phenomena of high and low pressure regions, as well as by those convection currents in which the general circulation of the atmosphere clearly enters into the phenomena. Here, again, the radiation temperatures above the prescribed level are not altered; those of the ground layers very little. Above this level, however, the absorption of the incident radiation is so small that the temperatures can be calculated from Table 1. We thus obtain with any desired exactness the temperatures of the stratosphere given by observation as temperatures of radiation equilibrium of these layers, determined by the ratio with which the water-vapor content absorbs the short and long wave radiation. The radiation theory furnishes the temperature of the stratosphere with any desired exactness. It gives a complete explanation of the thermal discontinuity which is connected with the mechanical discontinuity in the division of the atmosphere into troposphere and stratosphere. The radiation theory can not explain the mechanical discontinuity in the first place; nevertheless the possibility of establishing it is not excluded. To see this, we first of all make a distinction between our results and Gold's second result. If gray radiation is postulated, as with Gold,[8] the atmosphere is always arranged in a stable fashion by radiation, the absorption being an arbitrary function of the height. Starting from a convective state a separation of the atmosphere at $m=\frac{M}{4}$ can indeed be transitorily produced, so that convection currents are created in the lower part. But the final product is always stability; if the heat balance is null it is the isothermal state. On the other hand, our theory indicates that by radiation alone instability is continually produced in the lowest 3 kilometers of the atmosphere; in the lowest parts it is of such great intensity that a perpetual cause of convection currents is present. Consequently in an atmosphere which is not influenced by the general circulation a separation corresponding to the troposphere and stratosphere must occur on account of radiation alone at the height to which the convection currents extend. This height would be given by the condition that the underlying layers, intermixed by convection, send out just as much radiation as in radiation equilibrium; and it must be shown that the convection currents associated with instability can drive up to this height. It is not impossible that an admissible height will thereby be obtained, but then it will be uncertain and suspicious to ascribe the division of the atmosphere to these processes of radiation. Indeed the general circulation can surpass radiation in action determining temperature, and in the following paragraphs we shall consider that the air masses of temperate latitudes receive their radiating capacity not on the spot but, in fact, in the winter in equatorial regions, and have carried it to us from there. The induced instability, however, deserves close consideration in all cases, particularly in its action in regions and at times which are characterized by "radiation weather."

The calculated temperatures are proportional to the effective earth temperatures, the fourth powers of which are determined by the solar constant and the albedo of the earth. The first quantity is measured with sufficient exactness; a variation of the albedo by 10 per cent of its value would alter the effective earth temperature by about $4\frac{1}{2}$°, the inversion temperature, and thereby the temperatures of the stratosphere by about $3\frac{1}{2}$°. The agreement with observation would still be advantageous if we consider that we can compensate temperatures that are too low by a decrease in the water-vapor content of the stratosphere. It appears to me that a more suspicous simplification is that of spreading the flow of energy uniformly over the whole surface of the earth whereby this amounts to $\frac{2\times 0.63}{4}=0.315\ \frac{\text{gram cal}}{\text{min}}$ (albedo 0.37) leading to the effective earth temperature 254° = −19°C. For the yearly sum of the solar radiations for latitude 50 measures only 70 per cent and for the pole only 42 per cent of the value at the Equator. Even if we disregard the polar caps, the higher latitudes would, with the assumed distribution, receive too much, in case the geometrical conditions of the radiation were alone important in determining temperature. That it is not permissible, however, to introduce the effective temperatures for different parallels of latitude according to the amounts of radiation they receive is shown immediately by an attempt to take into account the influence of the seasons.

Thus in the summer half-year latitude 50° receives an amount of solar radiation represented by the number 183, in winter by 67 equatorial days,[9] for latitude 60° we get the numbers 169.5 and 38. The effective earth tempera-

[8] This statement is misleading, as Gold does not postulate gray radiation. The above is Emden's own interpretation of Gold's result.—*H. Bateman.*

[9] *Hann, J.* Handbuch der Klimatologie, Stuttgart ,1908, v. 1, p. 100.

tures (and the calculated radiation temperatures proportional to these) must behave like the 4th roots, for latitude 50° like 1 : 1.25, for latitude 60° like 1 : 1.45. The summer and winter temperatures of these parallels of latitude are 291.1°(18.1°C.) and 266°(−7°C.), respectively, and 287°(14°C.) and 257.2°(−15.8°C.), respectively, they thus behave only like 1:1.09 and 1:1.12, respectively. The temperatures of higher latitudes are thus not generated by solar radiation at the place. The solar radiation indeed governs the average yearly temperature of the earth as a whole; its variation with latitude and the deviations from a mean value during the year are determined by other factors. The general circulation of the atmosphere provides quantities of entropy to higher latitudes by the transportation of masses of air at higher temperatures, and in the same measure as it regulates the compensation of temperatures as the time of the year changes, it takes care also of the uniform distribution of temperature which lies at the basis of our theory. The temperatures of the lower layers of the stratosphere are, however, governed by the radiation of the deeper layers of the troposphere (we would otherwise meet with temperatures equal to the effective earth temperature); the general circulation consequently also hinders the otherwise strongly local and seasonal oscillation of the inversion temperature. Wagner's investigations [10] show, however, that the time of the year still has some effect, for the maximum temperature of the stratosphere in June was −52°C, the minimum temperature in January was −61.4°C. The oscillation of 9.4 degrees is smaller than the annual oscillation at the earth's surface. Our theory gives a satisfactory explanation. The atmospheric strata, and thus also the lower layers of the stratosphere, are richer in water vapor in the summer; the smaller the water-vapor content, the higher is the temperature of these layers. (See Table 1.) The lower temperature of the radiating layers of the troposphere is partly compensated by smaller water-vapor content at the upper inversion. The investigations of the following will give further insight into these conditions.

6. THE RADIATION OF THE ATMOSPHERE.

The investigations of the last paragraph determine the temperature of radiation equilibrium of the atmosphere in the case when the heat balance is given. In this paragraph we treat the converse problem. Let the temperature of the atmosphere and the outer radiation be given. What is the radiation which traverses each cross-section of the atmosphere and emerges at its boundary? We start from the same assumptions as before but E is now a given function of m and the equations may be integrated, giving

$$B_1 = \sigma e^{-b_1 m^4} \text{ and } B_2 = \overline{B}_2 e^{-b_2 m^4} + 4b_2 e^{-b_2 m^4} \int_0^m m^3 e^{b_2 m^4} E\, dm.$$

Taking into consideration the fact that $\overline{B}_2$ (the value of B at the upper limit of the atmosphere) is zero, we finally obtain after a simple transformation

$$B = \sigma\, e^{-b_1 m^4} - \overline{E}\, e^{-b_2 m^4} + E - e^{-b_2 m^4} \int_0^m e^{b_2 m^4} E'\, dm, \qquad (7)$$

where $\overline{E}$ denotes the value of E at the upper limit of the atmosphere. Likewise we find

$$A = \overline{A} e^{b_2 m^4} - 4b_2 e^{b_2 m^4} \int_0^m m^3 e^{-b_2 m^4} E\, dm,$$

and after a simple transformation

$$A = (\overline{A} - \overline{E})\, e^{b_2 m^4} + E - e^{b_2 m^4} \int_0^m e^{-b_2 m^4} E'\, dm. \qquad (8)$$

If instead of the values $\overline{A}$ and $\overline{E}$ at the upper limit we introduce the values $\underline{A}$ and $\underline{E}$ at the lower limit of the atmosphere ($m = M$) we obtain

$$A = (\underline{A} - \underline{E})\, e^{b_2(m^4 - M^4)} + E + e^{b_2 m^4} \int_m^M e^{-b_2 m^4}\, E'\, dm. \qquad (9)$$

Equations (7), (8), and (9) contain the complete solution of our problem.

If now we calculate the quantity

$$(2k_2 E - k_1 B_1 - k_2 B - k_2 A)\, dm \qquad (10)$$

we obtain the yield of energy for each layer and consequently the velocity of cooling. Integration with respect to m gives the yield of heat from atmospheric layers of finite thickness.

Applications of the above equations.

We first of all give a table of the temperatures at which a black body radiates certain quantities of energy, E, measured in gram-calories per square centimeter per minute. This unit will be denoted in future by G.

TABLE 3.—*Temperatures at which a black body radiates the energy E.*

T.....	210°A	230°	240°	250°	260°	270°	280°	285°	290°	300°	310°	340°
E.....	0.148 gr.-cal.	0.212	0.252	0.296	0.347	0.403	0.467	0.500	0.537	0.615	0.701	1.014

(1) *The nocturnal cooling of an isothermal atmosphere.*—Let the temperature be T. In consequence of the constancy of temperature, E is also constant, therefore $E' = 0$ and so $\overline{E} = \underline{E} = E$. Taking into account the nocturnal conditions we put $\sigma = 0$ in (7) and obtain

$$B = E(1 - e^{-b_2 m^4}) \qquad (11)$$

$$A = (\underline{A} - E) e^{-b_2(m^4 - M^4)} + E \qquad (12)$$

Since we wish to discuss the radiation of only the atmosphere itself, we assume further that the earth's surface is likewise at the same temperature and radiates like a black body, or finds itself at a somewhat higher temperature with a smaller capacity for radiation. so that we have $\underline{A} = E$ and we obtain

$$A = E \qquad (13)$$

The radiation B, which is not so important for our investigation, is uninfluenced by this simplification. Equation (13) again gives the theorem that an isothermal atmosphere does not alter the radiation of a black body at the same temperature. A horizontal surface reflecting on its upper surface and black on its lower surface would measure, at a place in the atmosphere, a radiation independent of the height and equal in intensity to the earth's radiation. When turned over the irradiated surface measures the radiation directed earthward which is given by (11). The factor $1 - e^{-b_2 m^4}$ is, as is easily seen, the absorption capacity of the layers lying above the level m, so that equation (11) is the expression of Kirchhoff's law, which holds here unchanged, since we assume

[10] *Wagner, A.* Die Temperaturverhältnisse in der freien Atmosphäre. Beitr. z. Physik d. fr. Atmosph., 1910, 3:57.
Dines, W. H., in Phil. trans., 1911, 211A:253.

an isothermal radiator. For the ground layer, $m=1$, we have $e^{-b_2 m^4}=0.1$ with average humidity conditions, so that the earth's surface receives, radiated to it from the atmosphere, a quantity of heat equal to 90 per cent of the quantity radiated by a black body at the same temperature! With increasing radiation the inflow of heat to the atmosphere decreases rapidly as the following table shows. The radiation is measured in *G's* as before.

TABLE 4.—*Inflow of heat to the atmosphere at different levels and temperatures.*

h	T				
	−20° C.	−10° C.	0° C.	10° C.	20° C.
Meters.	*G.*	*G.*	*G.*	*G.*	*G.*
0	0.28	0.32	0.38	0.44	0.50
1,000	0.23	0.27	0.315	0.37	0.42
2,000	0.18	0.21	0.23	0.28	0.32
3,000	0.12	0.14	0.16	0.19	0.22
4,000	0.08	0.10	0.11	0.13	0.15
5,540	0.04	0.05	0.055	0.06	0.07

Direct measurements [11] give—

Observed temperature.	Naples (60m).	Vienna (220m).	Zurich (440m).	Rawies (950m).	Sonnblick (3,100m).	
	22° C.	19°	15°	−6°	−1°	−12°
Counter radiation of the atmosphere	0.40	0.41	0.37	0.21	0.23	0.12

The differences (calculated − observed) are with one exception positive, decreasing with increasing height, the reason being that the calculations are based on temperatures which do not vary with the height.

In comparison with the previous numbers representing the relation between E and T, the numbers show how great the protecting effect (Strahlungsschutz) of an isothermal atmosphere is under ordinary humidity conditions. At sealevel the counter-radiation of this atmosphere amounts to 90 per cent of the outer radiation of the earth's surface when the latter has its maximum value (black-body radiation); it can thus keep the earth's loss of heat as low as 10 per cent. The extraordinary influence of the water vapor is also shown, for the decrease of the numbers with the height is to be ascribed chiefly to the water vapor.

To calculate the quantity of heat, dQ, given up by an atmospheric layer we find from (10) that

$$dQ=4Ee^{-b_2 m^4}b_2 m^3 dm, \tag{14}$$

and so

$$Q=E\ (e^{-b_2 m_1^4}-e^{-b_2 m_2^4}). \tag{15}$$

Consequently the layers lying above m give a quantity of heat

$$Q=E\ (1-e^{-b_2 m^4}),$$

which is the quantity furnished by the radiation B. The heat given up by this layer thus wanders only in the direction of the earth. This is evident because the constant energy current A, which leaves the atmosphere in the direction of space, enters at the lower surface.

The temperature of each layer falls in a minute by the quantity

$$\Delta T=\frac{4E}{c_p}e^{-b_2 m^4}b_2 m^3, \tag{16}$$

and the mean temperature of the layer from m_1 to m_2 by

$$\Delta T=\frac{E}{c_p(m_2-m_1)}(e^{-b_2 m_1^4}-e^{-b_2 m_2^4}). \tag{17}$$

The temperature does not fall at the same rate in all layers. The isothermal condition will consequently cease on account of the process of radiation, but very slowly. The layer $m^4=3/4b_2$ suffers the quickest change of temperature; this is at a height of about 2,250 m; with $T=270°$ its temperature sinks by 0.00323° per minute, and 5 hours 10 minutes are required for 1° of cooling.

To cool by 1° on the average, the lowest layer of 1 km. thickness requires 7 hours 20 minutes, the whole atmosphere 10 hours 45 minutes. The radiation processes of one night may consequently not alter an isothermal atmosphere in an essential way, the lowest dust-laden layers excepted; the low temperatures of the stratosphere do not react in a more appreciable way at the times of transition between night and day.

II. THE NOCTURNAL RADIATION OF A POLYTROPIC ATMOSPHERE.[12]

Using the same boundary conditions as in the last case we put $\sigma=0$ and $A=E$, since in any polytropic atmosphere the temperature decreases linearly with the height when g is constant $\overline{E}$ will be zero; equations (7) and (8) now give

$$B=E-e^{-b_2 m^4}\int_0^m e^{b_2 m^4}E'dm,\quad A=E+e^{b_2 m^4}\int_m^M e^{-b_2 m^4}E'dm.$$

To simplify the calculation as much as possible we put

$$E=E_0\frac{m}{M},\qquad M=1.$$

Since $m\sim p$ and $E\sim T^4$ we have the polytrope

$$\frac{T}{T_0}=\left(\frac{p}{p_0}\right)^{\frac{\kappa-1}{\kappa}}=\left(\frac{p}{p_0}\right)^{\frac{1}{4}}$$

thus $\kappa=\frac{4}{3}$; this gives the fall of temperature

$$\frac{dT}{dh}=-\frac{\kappa-1}{\kappa R}=-\frac{0.0085°}{\text{meter}}.$$

The temperature decreases by 0.85° per 100 meters, thus exceptionally rapidly when we take into account the above exceptionally small fall of temperature. We can thus estimate the radiation under average conditions. In paragraph 3 of his paper Gold has assumed the same temperature gradients. We are thus in a position to be able to compare his results with our theory. We thus obtain

$$B=E_0\left[m-e^{-b_2 m^4}\int_0^m e^{b_2 m^4}dm\right]. \tag{18}$$

$$A=E_0\left[m+e^{b_2 m^4}\int_m^M e^{-b_2 m^4}dm\right]. \tag{19}$$

The integrals can be evaluated by development in series which, since $b_2=2.3$, converge slowly for the maxi-

[11] *Trabert, W.* Lehrbuch der kosmische Physik. Leipzig, etc., 1911, p. 456.

[12] *Emden.* Gaskugeln. Leipzig, 1907. Chapter 17, §2.
The term "polytropic atmosphere" is used by Emden to denote an atmosphere or portion of an atmosphere in which the pressure, absolute temperature, and specific volume are connected by the relations

$$Tv^{\kappa-1}=\text{constant};\quad pv^{\kappa}=\text{constant}.$$

mum value $m = M = 1$, and the 10th term must be taken into account.

TABLE 5.—*The counter radiation B for different bottom temperatures, T_0, and altitudes, h.*

[Gram-calories per sq. cm., per minute.]

h	T_0 (air temperature at the ground).					
	−20°	−10°	0°	10°	20°	30°
M.	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*
0	0.26	0.29	0.335	0.39	0.45	0.51
1,000	0.18	0.21	0.27	0.28	0.32	0.36
2,000	0.12	0.14	0.155	0.18	0.21	0.24
3,000	0.07	0.08	0.09	0.11	0.13	0.14
4,000	0.04	0.05	0.05	0.065	0.07	0.08
5,540	0.015	0.02	0.02	0.03	0.03	0.03

The quantities of radiation radiated to the atmosphere are evidently smaller as in the case of an isothermal atmosphere, for B we obtain $0.798E_0$ instead of $0.9E$.

For the sake of comparison we give the few available observations and add the temperatures T_0 corresponding to the assumed gradient.

TABLE 6.—*Comparison of observed and computed temperatures and counter-radiations.*

	Naples (60 m.)	Vienna (220 m.)	Zurich (440 m.)	Rauris (950 m.)	Sonnblick (3,100 m.)	
Observed temperature	22°	19°	15°	−6°	−1°	−12°
Calculated to	22°	21°	19°	2°	25°	14°
Observed counter-radiation	0.40	0.41	0.37	0.21	0.23	0.12
Observed calculated isothermally	0.50	0.48	0.44	0.29	0.16	0.14
Observed calculated polytropically	0.46	0.42	0.38	0.24	0.14	0.12

The agreement with the observed values is as good as can be expected considering the difficulty of the measurements and the average conditions at the basis of the calculation. The disagreement of the measurement 0.23 on Sonnblick is an exception; in comparison with the other measurements, this value appears exceptionally large. *The agreement shows that with our simplifying assumption of dividing the radiation into short waves and long waves we form a very good estimate of the conditions actually obtaining.*

If, in order to approach closer to average conditions, we choose the exponent $\kappa = 7/6$ of the polytrope, we should obtain the temperature gradient 0.49° per 100 meters, and we should have to evaluate integrals of the form

$$\int_0^m e^{\pm b_2 m^4} m^{-\frac{1}{7}}\, dm.$$

For an atmosphere of this structure, we obtain $B = 0.838E_0$ instead of the values $0.798E_0$ and $0.9E_0$ just calculated. The two tables thus suffice for a judgment of the average conditions.

The radiation A can be calculated for each level from (19). In a free balloon at night the radiation $B + A$ would be obtained per horizontal square centimeter; it can serve as a measure of radiation.

For the radiation $\bar{A}$ which the atmosphere loses at its upper boundary, we obtain $\bar{A} = 0.7274E_0$, thus 73 per cent of the quantity which enters the atmosphere below. (For the temperature gradient 0.49 we get $\bar{A} = 0.826E_0$.) The atmosphere's gain in radiation is thus

$$E_0\,(1 - 0.7274 - 0.798) = -0.525E_0$$

gram-cal. per sq. cm. per minute.

It will consequently cool by about 0.00090 degree a minute, or by 1 degree in about 18 hours 30 minutes, if the ground temperature is 0°C. The time of cooling of the lowest kilometer is evidently smaller than 7 hours 20 minutes, the isothermal value. The cooling during the night is extraordinarily small.

To find the yield of heat dQ, we use (10) and (13) and obtain

$$dQ = \left[e^{-b_2 m^4}\int_0^m e^{b_2 m^4}\, dm - e^{b_2 m}\int_m^M e^{-b_2 m^4}\, dm\right] 4b_2\, m^3\, dm, \qquad (20)$$

and for a finite layer from m_1 to m_2

$$Q = e^{-b_2 m_1^4}\int_0^{m_1} e^{b_2 m^4}\, dm - e^{-b_2 m_2^4}\int_0^{m_2} e^{b_2 m^4}\, dm$$

$$+ e^{b_2 m_1^4}\int_{m_1}^{M} e^{-b_2 m^4}\, dm - e^{b_2 m_2^4}\int_m^M e^{b_2 m^4}\, dm,$$

where the quantity already calculated is again given for $m_1 = 0$, $m_2 = M$. In (20) $dQ > 0$ when m is large. For small values of m, we expand in powers of m and neglect m^4 and higher powers. The quantity within square brackets then becomes

$$2m - (1 - \tfrac{1}{5}b_2).$$

Thus

$$dQ \lessgtr 0 \text{ according as } m \lessgtr 0.27.$$

In all layers for which $m \lessgtr 0.27$ the outward radiation is $\lessgtr$ the absorption. The layers higher than $m = 0.27$ are warmed and the lower ones cooled by the radiation process. Let us calculate the height of this layer.

Since the temperature gradient is given by

$$\frac{dT}{dh} = -\frac{\kappa - 1}{\kappa R}$$

the polytrope

$$\frac{T}{T_0} = \left(\frac{p}{p_0}\right)^{\frac{\kappa-1}{\kappa}}$$

gives

$$dT = T_0 dp^{\frac{\kappa-1}{\kappa}}$$

if we put

$$p_0 = M = 1 \text{ and } p = m^{\frac{\kappa-1}{\kappa}}$$

We then obtain

$$1 - m^{\frac{\kappa-1}{\kappa}} = \frac{h(\kappa - 1)}{\kappa R T_0}.$$

Using our value $\kappa = 4/3$ and $m = 0.27$, we get

$$1 - m^{\frac{\kappa-1}{\kappa}} = 0.28 \text{ and for } T_0 = 273,$$

$$h = 8{,}950 \text{ meters.}$$

For the temperature gradient $0.49°/m$ we should have obtained 8,200 m.; for $0.1°/m$, 8,650 m.; increasing to ∞ for an isothermal atmosphere. Instead of our value $m = 0.27$. Gold found 0.25 under different assumptions as to the distribution of water vapor. Above this height a polytropic atmosphere would be warmed by the process of radiation; below it would be cooled.

III. ATMOSPHERIC RADIATION AND SOLAR RADIATION.

In order to free our ideas on the heating of the earth from many conventional obscurities, we ask the question: *Can the quantity of radiation which the earth's surface receives be increased by an absorbing atmosphere placed between the sun and the earth.* The answer is in the affirmative. Let us put the question in another form: Would the mean temperature of the earth's surface rise or fall if the atmosphere were taken away. At higher temperatures, i. e., with stronger outward radiation, more heat must also be conveyed to it. If the atmosphere justifies the idea that it is a heat conserver, thus increasing the temperature, it must augment the radiation.

The fact that an absorbing substance can strengthen the radiation passing through it appears paradoxical to us, since we involuntarily call to mind the laboratory experiments by which we determine absorption coefficients. The absorbing substance is interposed between the source of radiation and the receiving measuring surface. In this it is essential that the absorbing substance and measuring surface should be at a lower temperature than the source of radiation, so that only the weakening of the radiation is determined. With increasing temperature of the absorbing substance the conditions are completely changed. If for instance we take as a source of radiation a black glowing surface and interpose a cold gas, the dark absorption lines appear; with a hotter gas, the emission preponderates in spite of the absorption and the lines appear bright. If, on the other hand, we take care that the radiating and absorbing (receiving) bodies can only exchange heat among themselves by radiation, then radiation equilibrium for this system sets in and every absorbing body emits black radiation.

The earth's surface without an atmosphere would set itself at the effective earth temperature if the sun's radiation were uniformly distributed. If we again add the atmosphere, assume gray radiation, and await radiation equilibrium, the atmosphere sets itself isothermally at the same temperature and each layer is traversed upward and downward by the same energy current independently of its height. The radiation which the earth's surface receives remains unaltered, and the "heat conservation (Wärmeschutz)" of this atmosphere would be null. Strictly speaking, it would be negative. Diffuse reflection and clouds diminish the useful radiation by 37 per cent, the value of the albedo; but we omit this quantity of energy in practice, since it does not enter into the thermodynamical system and is always left out of consideration.

If we abandon the hypothesis of gray radiation, which leads to unsatisfactory results, and again divide the radiation into short and long waves, the earth's surface is met in radiation equilibrium by radiation B determined by equation (4) of paragraph 4. Denoting by σ the radiation incident on the upper limit of the atmosphere we get

$$\underline{B}=\sigma(2.2)^{\frac{1}{4}}=1.218\sigma.$$

There is conservation of heat; the interposed atmosphere strengthens the incident radiation by about 22 per cent. The mechanism of the radiation process is clear. The atmosphere is warmed not only by the radiation incident from above, σ, but chiefly by the counter-radiation from the earth's surface, and this counter-radiation is itself governed by the solar radiation and the counter-radiation of the atmosphere. The radiations $\underline{B}=\underline{A}=1.218\sigma$ are diminished by the absorption and emission of the atmosphere to the values $\overline{B}=\overline{A}=\sigma$ at the upper boundary, so that the balance of heat is null for the whole.

The convection currents of long cycles hinder the formation of radiation equilibrium within the troposphere. The temperatures of the stratosphere are not altered thereby; its low temperature and small content in water vapor permits it to send out only small quantities of radiation. The counter-radiation of the atmosphere is governed almost exclusively by the condition of the troposphere, particularly in the layers near the earth. Consequently we come very close to average conditions when we assume a decrease of temperature of 0.5° per 100 m.; the temperature conditions of the lower important layers are sufficiently well represented thereby. The counter-radiation is estimated with sufficient exactness as

$$\underline{B}=0.84\underline{E}_0=0.84s\underline{T}_0^4, \qquad (21)$$

where T_0 measures the ground temperature of the atmosphere. In order to take into account as far as possible the conditions actually obtaining, we abandon the assumption that the solar radiation is distributed uniformly over the earth's surface; that this is throughout at an average temperature. We make an investigation taking into account the geographical latitude. Accordingly we put for T_0 in (21) the mean temperature of the parallel of latitude, using Spitaler's values for the year, for July, the warmest month, and for January, the coldest month. We thereby calculate the counter-radiation ($\underline{B}$) of the atmosphere and compare it with the radiation which the sun sends to this parallel of latitude with the full quantity of radiation $\sigma=2$ *G's without subtracting the albedo.* (It would be too troublesome and uncertain to calculate the albedo of each parallel of latitude.) The results of the calculation are given in Table 7.

TABLE 7.—*Solar radiation and the atmospheric counter radiation for certain parallels of the Northern Hemisphere. (Emden, p. 136, Table II.)*[13]

[Gram-calories per square centimeter per 24 hours.]

North latitude.	Temperatures. Annual.	July.	January.	Mean annual solar radiation.		Mean annual counter radiation.
	1	2	3	4	5	6
	°C.	°C.	°C.	*Equatorial days.*	*Gram-calories.*	*Gram-calories.*
0°	25.9	25.5	26.2	365	880	733
15°	26.3	27.9	23.9	354	852	736
20°	25.6	28.1	21.7	345	830	732
30°	20.3	27.4	13.9	321	773	681
40°	14.0	23.8	3.9	288.5	694	624
50°	5.6	18.1	— 7.2	250	601	554
60°	—0.1	14.1	—16.0	208	500	510

North latitude.	Solar radiation, June 21.		Counter radiation, July.	Solar radiation, Dec. 21.		Counter radiation, January.
	7	8	9	10	11	12
	Equatorial days.	*Gram-calories.*	*Gram-calories.*	*Equatorial days.*	*Gram-calories.*	*Gram-calories.*
0°	381	917	730	358	863	736
15°	387	933.5	753	285	687	713
20°	398	958	755	258	621	694
30°	411	998	750	198	477	622
40°	421.5	1,015	713	135	326	540
50°	421	1,015	660	75	181	460
60°	416	1,002	624	21	51	403

[13] The quantities of solar radiation in equatorial days are taken from *Hann*, Handbuch der Klimatologie, Stuttgart, 1908. Bd. I, p. 94. At the time when day and night are equal the equator receives $1440\sigma/\pi=458.4\sigma$ gram. cal./cm², 24 hrs.; the wandering of the sun between the tropics (Wendekreise) makes this quantity 0.9592 times smaller on the yearly average. An equatorial day thus corresponds to a supply of heat equal to $0.9592\times458.4\sigma=439.7\sigma=879.4$ gram-cal./cm²., 24 hrs.

We first consider the mean yearly conditions. In the equatorial regions themselves the counter radiation of the atmosphere is only about 20 to 10 per cent smaller than the inflow of radiation at the upper boundary. Since the content of the atmosphere in water vapor is certainly greater than the assumed mean value in these regions, the counter radiation is still greater. (Since we put $B = 0.84 s T_0^4$, it can be always about 16 per cent greater.) Between latitudes 50° and 60° the two radiations are already equal to one another. A considerable part of the calculated solar radiation is, however, lost for radiation to the earth by reflection at the clouds and by diffuse reflection. If we estimate the diffusely reflected portion at 19 per cent, as usual, the solar radiation will be already reduced below the atmospheric radiation. We thus have the theorem:

The annual counter radiation of the atmosphere is only a little smaller than the annual solar radiation which the atmosphere encounters at its outer limit, and is greater than the annual solar radiation which arrives at the solid earth.

If we reduce the given value of the solar radiation by 37 per cent, the mean value of the albedo, we obtain between latitudes 0° and 30°—or for half the earth's surface—about $840 \times 0.63 = 530$cal.; in the assumed polytropic atmosphere the outward radiation of earth + atmosphere would be almost exactly equal to the given values of the counter radiation; for on page 22 we found the gradient 0.49°/100m to give $B = 0.84 E_0$, and $A = 0.83 E_0$.

The heat balance would thus no longer be zero, since in the course of the year more heat would be radiated outward than inward. But the assumed gradient holds only for the lower layers of the atmosphere which chiefly determine the counter radiation. By assuming this gradient we have ascribed far too high temperatures to the upper layers which govern the upward radiation; at heights of 10 kilometers we would obtain −25° to −30°C instead of −50° to −57°, the temperatures of the stratosphere. The outward radiation consequently turns out to be much smaller.

If we calculate with the radiation of the stratosphere in radiation equilibrium, we obtain instead of an average of about 720 cal./cm² 24 hrs. of counter radiation, the amount $1440 \times 0.315 = 455$ cal./cm² 24 hrs. compared with the 530 incident calories. Since, however, with increasing latitude the atmospheric radiation preponderates, the heat balance is found to be zero with sufficient exactness.

The figures in Table 7 enable us to compare the greatest and smallest counter radiation of the atmosphere with the greatest and smallest daily solar radiation. It was to be expected that with increasing latitude the solar radiation at the time of the sun's greatest altitude would always exceed the counter radiation. It is surprising, however, to what extent the counter radiation of the atmosphere preponderates at the time when the sun is lowest. If we reduce the 181 calories of solar radiation which fall on latitude 50° by the value of the albedo, we obtain 110, while the counter radiation provides 460 calories. In central Europe the earth's surface receives two or three times as much heat from the counter radiation of the atmosphere as from solar radiation.

In order to be able to estimate the conserving effect of the atmosphere in another way, we have prepared Table 8.

TABLE 8.—*Showing the thermal conserving effect of the atmosphere. (Emden, p. 139, Table II.)*

North latitude.	Year.				Summer half-year.			Winter half-year.		
	Solar radiation.	Temperature.			Solar radiation.	Temperature.		Solar radiation.	Temperature.	
		Radiation.	Measured.	Difference.		Radiation.	July.		Radiation.	January.
	1	2	3	4	5	6	7	8	9	10
	Eq. da.	°C.	°C.	°C.	*Eq. da.*	°C.	°C.	*Eq. da.*	°C.	°C.
0°	365	26.5	25.9	−0.6	182.0	26.5	25.5	182.6	26.5	26.2
10°	360	25.6	26.3	0.7	193.3	37.8	27.9	166.9	19.1	23.9
20°	345	23.1	25.6	2.5	198.5	32.9	28.1	140.7	10.6	21.7
30°	321	17.1	20.3	3.2	198.4	32.9	27.4	122.6	− 2.9	13.9
40°	288.5	9.3	14.0	4.7	193.0	30.7	23.8	95.6	−18.2	3.9
50°	250	− 0.7	5.6	6.3	182.9	26.6	18.1	66.8	−40.0	− 7.2
60°	208	−12.8	− 0.1	12.7	169.5	21.1	14.1	38.2	−73.2	−16.0

We denote by "radiation temperature" the temperature to which the earth's surface is brought by the incident solar radiation on the assumption of gray radiation (temperature of radiation equilibrium). If the radiation does not last too short a time, say a few days, then the earth's surface would set itself at this temperature, since heat conduction plays only a secondary part. The second row contains these radiation temperatures for the different latitudes with average annual radiation. The observed mean annual temperatures of the atmosphere are only slightly higher, about 6°C. in latitude 50° north. This is an extraordinary quantity for climatic conditions, but from the thermodynamical standpoint, which here alone is important, we have to compare with the absolute temperature and we thus obtain a difference of only 2 per cent. *The average yearly heat conservation of the atmosphere is accordingly very small.* Columns 6 and 7 give the "radiation temperature" for the mean radiation of a summer half-year and the July temperatures. In the summer half-year the heat conservation of the atmosphere is negative.

The heat consevation in winter is surprisingly great. The mean winter radiation of the sun gives extraordinarily low radiation temperatures (they would be still lower for December radiation), even in north latitude 20° they lie 11 degrees below the January temperature. If there were no atmosphere, the 50th parallel would set itself at an average temperature of −40° in the course of the winter, and the 60th parallel would come to −73° C; the atmosphere raises these temperatures by 33 and 57 degrees, respectively. Consequently *in winter we obtain an extraordinarily large positive heat conservation, in summer a small negative one, and in the course of the year a small positive one.* These relations are repeated to a lesser degree during day and night.

Angot's well-known investigations on the distribution of the sun's radiation with reference to the atmospheric absorption are consequently of but small importance; they give only the influence of the atmosphere on the direct solar radiation. The smaller the transparency of the atmosphere, the more will the higher latitudes and the winter be set at a disadvantage in comparison with summer. If, however, we are dealing with the utility of the sun's radiation for the heating of the earth and its

covering, the matter is quite different. The more the atmosphere emits (absorbs) the more does the sun's radiation pass in this roundabout way to the higher latitudes, to a large extent in winter but to a less extent in the whole year. In summer its heat conservation is negative, but in winter we benefit from solar radiation which is conveyed to the higher latitudes in a roundabout way by atmospheric radiation. The fact that the "radiation temperature" of central Europe is increased to the extent of 30 to 60 degrees (C.) by the counter radiation of the atmosphere shows that the atmosphere has not received its great capacity for radiating by being irradiated in these latitudes. The general circulation of the atmosphere—which is particularly active in winter on account of the large temperature differences—brings into higher latitudes masses of air capable of radiating and furnished with great quantities of entropy in the equatorial regions. The general circulation may be compared with a huge föhn, which ascends in the tropical belt of calm, flows over the trade-wind region and the horse latitudes and in descending is capable of radiating profusely on account of the high potential temperatures at moderate water vapor content.

In order to decide whether heat is conveyed to the higher latitudes and land masses chiefly only by solar radiation and atmospheric radiation, we have still to take into account the influence of the process of condensation. If water vapor condenses, quantities of entropy become available so that work and the yielding of heat can be combated. If the performance of work is sufficiently small, then in case the condensation takes place at 0°, the yield of heat is about 600 $\frac{\text{gram cal}}{\text{gram}}$ (at $-10°$, 0°, $+10°$, it is 613, 607, and 589 cal., respectively). If we take a yearly rainfall of 120 cm, the condensation provides daily about 200 $\frac{\text{gram cal,}}{\text{cm}^2}$ while the counter radiation of the atmosphere is about three times this quantity. Now, Brückner [14] has shown that each drop of rain falls to the ground, on the average, three times before it is again returned to the ocean, consequently two-thirds of the heat made available by condensation is taken up from the land in evaporation. With a yearly rainfall of 120 cm, the quantity of heat brought by the water vapor taken from the ocean and made available by condensation is only 67 $\frac{\text{gram cal,}}{\text{cm}^2, \text{ 24 hrs}}$ thus about 10 per cent of the counter radiation of the atmosphere, while over the ocean itself, the ratio is smaller. The gain of heat from condensing water vapor is small compared with the gain by radiation from radiating masses of air warmed in tropical regions.

The investigations of this paragraph were founded on a constant average content of water vapor in the atmosphere. The absorption capacity of the atmosphere as a function of the humidity is far too scantily known for us to be able to take into account with any certainty the variability of the humidity with regard to place and time. This quantity which is of such importance for the conservation of the earth's heat can be obtained by systematic measurements of the counter radiation of the atmosphere by means of the theory developed here.

[14] *Brückner, E.* On the origin of rain. Geographische Zeitschrift, 1900, 2:89.

A TORNADO IN UTAH.

By ARTHUR W. STEVENS, United States Forest Service.

[The following report is transmitted through A. H. Thiessen, meteorologist, Salt Lake City, Utah, who remarks that the phenomenon is so very unusual in Utah that more than ordinary interest attaches to it.]

A small tornado occurred to-day (August 5, 1916) in the valley of the East Fork of the Sevier River about 1 mile north of Dave's Hollow ranger station, elevation 7,800 feet.

As observed from the station, the tornado appeared to have formed a short distance east of Frank Hatch's ranch on the Tropic Road. When first observed it was in the form of a slender inverted cone. It was too far distant to observe any whirling motion, but small puffs of cloud-like smoke were traveling rapidly upward on the outer surface of the cone.

The cone elongated rapidly and took on the shape of a rat's tail. The tip of the cloud did not touch the ground at any time, but directly under it was a large whirlwind that lifted a spray of mud and water from the ground.

The whirling cloud was white and at times appeared almost luminous, probably by contrast with the exceedingly dark cloud back of it.

The tornado lasted about 15 minutes, and traveled not over one-half mile in an easterly direction before breaking up.

After the storm I rode over the area of the storm, but as the only vegetation was sage brush and similar plants not over a foot high, there was no evidence to show exactly where the tornado had passed. The strip of ground affected was probably not over 20 or 25 feet wide, and possibly narrower than that.

This occurred during a period of exceptionally violent local rain and thunderstorms. Ranger Houston, of Dave's Hollow, pronounced it a waterspout, and I think it was so entered in his weather report for the day; but it was undoubtedly the same as the "twisters" of the Middle West, and the occurrence of one west of the Rockies was thought to be sufficiently rare to be worth recording.

THE GOVERNMENT SAFETY-FIRST TRAIN, 1916.

By RUY H. FINCH, observer in charge of Weather Bureau Exhibit.

[Dated Weather Bureau, Washington, Sept. 25, 1916.]

During the summer of 1916 a unique method was pursued in informing the public as to some of the work that is being done by the various branches of the Federal Government.

While a great many people have had an opportunity to visit the different international expositions, and the National Capital, yet the vast majority of our citizens have but little knowledge of Federal activities.

After the Safety-First Convention, held in the New National Museum where most of the departments of the Government had exhibits, the idea was conceived of placing the exhibits on a railway train and giving everyone an opportunity to see what the Government is doing in the way of safeguarding life and property. Accordingly, a selection of exhibits was made and placed in 10 steel coaches, from which the seats had been removed, of the Baltimore & Ohio Railroad. Thus the Government Safety-First Train, a "World's Fair on wheels," originated, and on May 1, 1916, it started on its four months' educational trip.

The exhibits were arranged on both sides of the cars, or so as to leave a passageway from one end to the other,

and the people coming in at one end would pass entirely through the 10 exhibition coaches. Government attendants and demonstrators were stationed beside their exhibits and explained them as the people passed through the train.

The following departments had exhibits: Agriculture, Interior, Navy, War, Treasury, Interstate Commerce Commission, and American Red Cross. The Department of Agriculture was represented by three of its branches—Weather Bureau, Forest Service, and Bureau of Animal Industry—each having one-third of a 70-foot coach.

The Weather Bureau exhibit, shown in figure 1 opposite, consisted of charts and pictures, storm-warning lanterns, a model of a house showing a system of lightning conductors, a glass weather map, and most of the meteorological instruments that would permit of being carried on a train.[1] All were selected with a view of showing, in the small space available, the work of the Weather Bureau in observing and recording weather conditions and forecasting the weather, including frost, cold waves, storms, and floods. A striking chart was one that contrasted the number of lives lost during a hurricane of 1893—before the organization of the Weather Bureau's West Indian service—with the number lost during a storm in 1915. The model house with lightning rods attracted considerable attention and from a practical educational standpoint was second to no other exhibit on the train. The method of forecasting was shown by the aid of the glass weather map, which was drawn every day, and most people expressed themselves as being much pleased with the opportunity of learning the basic principles of forecasting.

The explanation of the instruments was made easy by having them so placed that all could be seen at once. The triple register was in actual operation; an electric light actuated the sunshine recorder, the cups of the anemometer were rotated by an electric fan, a sprinkling can was the source of many showers, and the wind vane could record three different directions. Both tipping bucket and ordinary raingages were exhibited in operation and attracted more attention than any other of the Weather Bureau instruments.

The train was operated by the Baltimore & Ohio Railroad for two months, and one month each by the Missouri, Kansas & Texas Railway and the Union Pacific Railroad companies. In all, it traveled 10,000 miles, was exhibited in 87 cities of 16 different States. The total attendance was 534,000, giving an average daily attendance of 5,180 for the four months that it was on the road.

While the large number of people attending precluded their seeing the exhibits as thoroughly as was desired, yet the trip as a whole was a success.

GRAPHICAL METHOD OF SHOWING THE DAILY WEATHER.[2]

E. T. QUAYLE, Assistant.

[Commonwealth Bureau of Meteorology, Melbourne, Australia.]

(*Reprinted from* Geographical Review, New York, Sept., 1916, 2:233.)

A simple method of keeping a graphic record of the daily weather has many advantages over the usual written description. Mr. E. T. Quayle, assistant in the Commonwealth Bureau of Meteorology of Australia, has recently described a simple scheme for a graphic record which he has used satisfactorily for over twenty-five years. The record deals chiefly with cloud types and their amounts, movements, and changes, but includes also winds, rain, and electrical and other phenomena. The time (hour of the day) is shown along a horizontal line, and the cloud levels are indicated vertically. The cloud forms are represented as seen in section, or as they would appear on the horizon. The level to which the cloud belongs is indicated by the height of its position on the vertical scale of the diagram. The amount of cloud and its duration are partially suggested by the way the stratum is broken or by the addition of a figure to show a numerical estimate. The rate of movement may be shown by different amounts of feathering on arrows which show the direction of movement. Wind directions are indicated by arrows at the bottom of the diagram. Rain, lightning, etc., are suggested by conventional symbols or by sketches. Short supplementary notes may be added when necessary. The illustrations of this method of keeping a graphic weather record, given in Mr. Quayle's report, show the value of the scheme in presenting at a glance a vivid and interesting picture of each day's weather.—*R. DeC. Ward.*

[1] The objects of this exhibit were illustrated in more detail in the plates facing pp. 432-3, of the REVIEW for September, 1916.

[2] *Quayle, E. T.* A graphical method of showing the daily weather, especially cloud types. Melbourne, 1916. (Commonwealth Bureau of Meteorology, Bulletin 12.)

TOWER CLOUD AT SAN JUAN, P. R.

By F. E. HARTWELL, Meteorologist.

[Dated: Weather Bureau Office, San Juan, P. R., Aug. 16, 1916.]

About half an hour before sunset August 15, 1916, at San Juan, P. R., the sky being otherwise absolutely clear, a large flat-topped cumulus cloud was observed silhouetted against the western sky. A perfectly smooth band of false cirrus lay across the top and extended over the edge of the dark cumulus, the formation being such that it seemed to indicate the foreshortening of a wide curve in the overhanging edge of the band, which was luminous from the setting sun behind it.

From this stage the cumulus rapidly assumed the formation of [a wide cumulus chimney] with a cap of the false cirrus arranged in four distinct bands, thin enough to show their circular form; the top and broadest band was luminous, the other three narrow ones were in the shade of the dense cloud. No motion could be detected in these bands, so smooth was their texture, but it would seem that they could have been held in such a form only by a circular motion. These bands persisted with very little change for 20 minutes or more, the upper disk or band disappearing first and then what appeared to be the edges of two similar disks appeared a little below the bases of the original narrow disks.

The height of the cloud at its maximum development with its triple crown was about 30°; there were frequent lightnings through the middle of the cloud column, but the distance was so great that no thunder was heard.

The above note and description, with its unpublished sketches, relates to a cloud form rarely if ever *reported* from the Western Hemisphere. Similar and related forms have been figured and described in the Meteorologische Zeitschrift, notably in its issue for January, 1896 (**13:** 14–15 with Tafeln I, II).

The present form differs in some details, however. There are no radial fringes suggestive of matter being hurled out from within the bands (cf. sketch in Met. Ztschr., Nov., 1901, **18:** 527); neither is there a strongly developed over-hang to the bands; the sketch shows but a slight leaning outward.

Mr. Hartwell does not mention associated hail falls, and we must wait for later reports before it can be asserted that in this case the cloud is properly termed a Hagelturmwolke (hail-tower-cloud), as was the one described by Streit in the Meteorologische Zeitschrift.—C. A., jr.

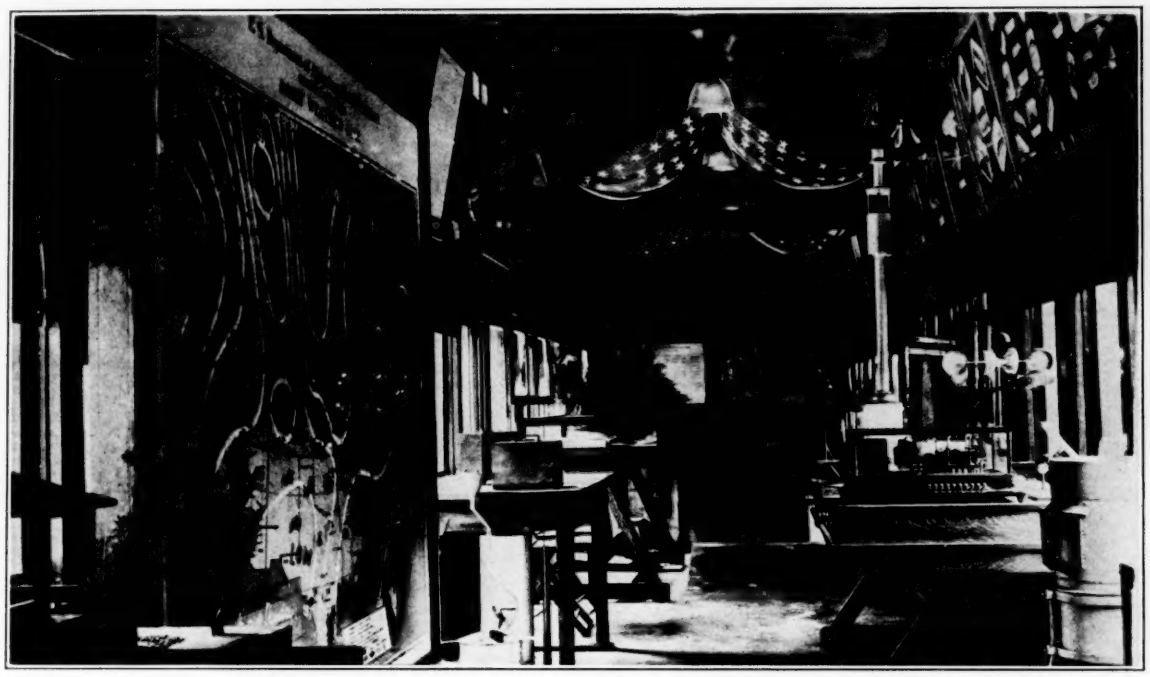

FIG. 1.—View of U. S. Weather Bureau exhibits on the "Safety-First Train," 1916.

SECTION III.—FORECASTS.

FORECASTS AND WARNINGS FOR AUGUST, 1916.

By ALFRED J. HENRY, Supervising Forecaster.

[Dated Weather Bureau, Washington, Sept. 19, 1916.]

HIGHS.

During the month of August, 1916, nine highs, mostly of feeble intensity, passed east-southeast as shown by Chart II (XLIV–86). The main path of the highs was southeastward through the Dakotas and the Middle Missouri Valley but after leaving that region they diminished greatly in intensity.

LOWS.

Sixteen primary LOWS and one secondary, were charted during the month. This number includes two tropical cyclones, Nos. VIII and XIII of Chart III (XLIV–87), but does not include the tropical cyclone of August 29–31 that passed westward over the Caribbean and apparently dissipated over the Yucatan Peninsula on September 1.

Practically all of the extratropical LOWS of the month passed eastward north of the Great Lakes and there was a marked tendency toward the development of a trough of low pressure extending to the southwest of the center of the LOW as soon as the latter passed the Great Lakes. In August 50 per cent of the LOWS which appear on the daily weather maps of the Weather Bureau have their origin in the Province of Alberta. The remaining 50 per cent have their apparent origin over the north Pacific Coast States, the northern and middle Rocky Mountain regions, respectively, or they may develop as secondary disturbances over the Central Valleys east of the Plains States.

The LOWS of the current month were largely of the Alberta type and their eastward movement after reaching the Missouri Valley was well to the northward of the Great Lakes. The north component of the LOWS and the fact that not a single disturbance developed in the Gulf and South Atlantic States or moved northeastward from that region are the prominent features of August weather in the United States.

Tropical cyclone of August 12–18.

Three tropical cyclones appeared during the month. The first, a portion of whose path is shown as No. VIII of Chart III, was first observed on the morning of the 12th in the vicinity of Barbados; it passed westward a short distance south of Jamaica on the 15th and into the Gulf of Mexico by way of the Yucatan Channel on the night of the 16th; it was approaching the south Texas coast on the morning of the 18th, and passed inland between Corpus Christi and Brownsville the afternoon and evening of the 18th.

Advices of the probable location and movement of this hurricane were sent to all Gulf ports beginning on the 13th and continuing twice daily until definite warnings were issued on the morning of the 18th. A notification of the approach of this storm was also wired to the commanding general at San Antonio, Tex. Some of these advices are published in District Forecaster Cline's report, page 463.

Six lives were lost by the foundering of the coastwise steamer *Pilot Boy* off Port Aransas, Tex.; three additional lives were lost by drowning along the coast near Corpus Christi, Tex., and six at various interior points, as a result of hurricane winds in the lower Rio Grande Valley.

Newspaper reports place the damage sustained in southwest Texas at $1,800,000. The damage, while largely confined to coast regions, was more or less general over a wide area. In the interior, crops were badly damaged by wind and rain and windmills, fences, and barns were blown down.

Observer W. F. Lehman, in charge of the Weather Bureau office at Corpus Christi, makes the following report on the storm.

Corpus Christi, Tex.—The first indications of the approach of the tropical cyclone that visited the western Texas coast region on August 18, 1916, were observed at Corpus Christi on the night of the 17th. The barograph recorded a wavering line, scarcely differing more than one-hundredth from a straight line, from 7 p. m. till 12 midnight, instead of showing the usual rise of about six-hundredths of an inch between 7 p. m. and 10 p. m. The wind, which had been light to gentle easterly during the day, shifted to northeast about 10 p. m. and to the north at 11 p. m. A clear sky with a few strato-cumulus clouds had prevailed since 5 p. m. and was still clear at midnight. Cirrus and cirro-cumulus clouds from the east had been observed during the day, but their prevailing direction had been easterly since the middle of July.

In the early morning of the 18th the barometer began to fall slowly, and the wind, still from the north, increased from light at 1 a. m. to 22 miles at 7 a. m. Cloudiness also increased. Coming from the east, a layer of dense alto-stratus gradually advanced with a well-defined west front. At 5 a. m. about four tenths of clear sky could still be observed. The clouds soon assumed the shape and density of strato-cumulus, and at the time of the morning observation covered eight-tenths of the sky, with a sharply defined area of clear sky in the west.

The first light shower occurred at 7:45 a. m., and a thunderstorm, coming from the northeast and attended by moderate rainfall, passed over the city between 9:40 and 10:35 a. m. The wind, which had reached a velocity of 40 miles at 9:35 a. m., changed to light and moderate northeast during the passage of the thunderstorm, but soon resumed its north direction and squally character.

The barometer, after registering the usual thunderstorm nose, fell rapidly, and the wind increased in intensity, attended from 11:55 a. m. on by a steady rain which did not end until late at night. At 1:53 p. m. a maximum velocity of 64 miles was recorded with an extreme of 70 miles. The direction of the wind soon after changed to northeast and its velocity decreased to the force of a strong gale from 3 to 5:30 p. m.

The first squall of hurricane force occurred at 5:45 p. m. It was the beginning of straight east winds, veering occasionally between east-northeast and east by south. The barometer reached its lowest point, 29.05 inches—29.07 reduced to sea level—at 6:15 p. m., but the wind attained its highest velocities during the subsequent two hours and a half. Estimated maximum velocities of 90 miles were reached at 6:50, 7:18, 8:15, and from 8:40 to 8:50 p. m., the barometer rising rapidly after 6:45 p. m.

From 6:30 p. m. on all the meteorological notes except the barograph curve had to be recorded by eye observation or estimation, since the wind instruments were wrecked and the windowpanes in the instrument room were shattered, burying the mechanism of the automatically registering instrument under glass splinters. The barometer box was fixed solid to the wall, and as there was no safer place to take the barometers to—it was not thought that the windows in the other office rooms would hold out much longer—they were well protected and the room was closed up.

After 9 p. m. the wind subsided, and at 11:30 p. m. it shifted to a southerly direction. The wind continued to blow in gusts till late in the forenoon of the 19th and became light after 7 p. m. A period of unusually light winds and calms, lasting five days, followed the storm.

The total rainfall for the day amounted to 1.58 inches, but this record is unreliable, as much of the rain was blown straight across the roof of the building, and such quantities as fell into the rain gage were mingled with salt-water particles from the bay, only a block distant from the

office. The water drawn from the rain gage had a decidedly brackish taste.

From reports of reliable observers, gathered at this office, the storm center passed inland a little south of Riviera, situated 45 miles south of Corpus Christi. At this place the wind blew from the north until about 8 p. m. and after a half hour's easterly direction came straight from the south. At the office of the Santa Gertrudis ranch, at Kingsville, 14 miles north of Riviera, the aneroid barometer was carefully watched by Mr. J. B. Wright, the manager of the ranch, and he took the lowest reading of 27.70 inches at 8:15 p. m. This instrument showed, on comparison, that it registered three-tenths too low, and it was sent to this office for adjustment. After being adjusted two day's observations and comparisons failed to show any difference in readings between our station barometer and this aneroid.

Hurricane warnings were received and sent out early in the forenoon. Considering local weather conditions and the 7 a. m. barometer readings of regular Weather Bureau stations on the Texas coast, there could be doubt about the course of the storm. It was also expected that telegraph wires would go down early and that the storm, which few, if any, had apprehended only 12 hours before, would reach its fullest strength on the coast about sunset. The coast places were warned first. Some fishermen had already ventured out at dawn in the bay and the lagunes; of these two were drowned. Then warnings that a hurricane was approaching the Texas coast between Corpus Christi and Brownsville and that its full force might be expected sometime at night were sent out for dissemination to all places from Calhoun to Cameron Counties that could be reached by telegraph or telephone. Even as early as 10 a. m. about 20 of the addresses to be advised by telegraph could not be reached on account of wire trouble and had to be sent by telephone.

At 1 p. m. it was thought expedient to warn the city authorities that the worst might be expected between sunset and midnight and that people living in light frame houses should seek shelter in substantial brick buildings for the night. A volunteer brigade of about 100 automobiles was organized, and these were busy from 1 till 5 p. m. in bringing women and children from the outskirts of the city to the safer buildings of the business section. This work was greatly aided by the decrease in wind velocities between 3 and 5:30 p. m. City Hall, hotels, banks, and schoolhouses were filled with refugees, which, while not comfortable, felt at least safe and at ease.

Of the people that thronged the local office of the Weather Bureau during the day a surprisingly large percentage were visitors who had spent their last summer's vacation at Galveston and had come to Corpus Christi this year in order to escape another hurricane. It was the settled conviction of even the oldest inhabitants that Corpus Christi lay outside of the path of destructive storms. Thus many did not trouble themselves with protecting such property as could have been saved, and afterwards were glad that they and their families escaped with their bare lives.

Of the death toll exacted by the storm: six of the crew of the steamboat *Pilot Boy*, coming from Galveston, forewarned, perished when the boat was wrecked in the entrance of Port Aransas Harbor. The two fishermen mentioned before and a boy aged 14 complete the list of those drowned. Three unidentified Mexicans were killed in Willacy County, and an aged Mexican and his wife were found dead in their demolished home 7 miles southeast of Alice, Jim Wells County. Three warnings had been sent to Alice and were acknowledged with thanks. The death of an unidentified Mexican woman was reported from San Diego, Duval County.

The property loss in the entire hurricane affected district is estimated at $1,600,000, the cities of Bishop, Kingsville, and Corpus Christi being the largest sufferers. In Corpus Christi it was the water front that sustained the heaviest damage. All the wharves and most of the buildings on the wharves were destroyed, even the solid timber head of the municipal wharf was unfloored, taking down the storm-warning display tower. Hardly a property in Corpus Christi escaped without damage of some kind, and vegetation where not destroyed suffered heavily. Many of the picturesque salt cedars, the pride of Corpus Christi, were blown down.

There can be no question but that the storm was a fully developed hurricane with a central pressure at least 1 inch lower than that observed at Corpus Christi. The relatively low property losses along the coast must be ascribed to the rapidity with which the storm advanced and passed. Because of this rapidity of movement its chance of creating a big tidal wave were greatly diminished. Also it must be borne in mind that the whole length of the Texas coast is protected by sand islands stretching from the mouth of the Rio Grande to Galveston, with few inlets and sparsely settled.—*W. F. Lehman.*

After passing inland a short distance south of Corpus Christi, the cyclone continued to move in a west-northwest direction, reaching Del Rio, Tex., north latitude 29° 20′, west longitude 100° 53′, at about 7:30 a. m. local mean time August 19, with a minimum pressure of 28.69 inches. Since it passed Corpus Christi, 200 miles distant, 12 hours earlier, we may assign it a movement of about 17 miles per hour. The recovery of the pressure after the passage of the center of the storm was extremely rapid. By 10 a. m. the barometer was slightly higher than the value it had 24 hours previous. The next observing station in the path of the storm is El Paso, Tex., distant about 300 miles. The barograph at that and other stations in that vicinity do not show any trace of the storm in question; we must therefore consider that it dissipated over southwest Texas during the daylight hours of the 19th.

It is worthy of note that all three tropical cyclones of August, 1916, were characterized by remarkably small diameters and naturally extremely steep barometric gradients near the center only. Two of them surely, and possibly the third, passed into the eastern Caribbean with practically no premonitory signs, and by reason of their small diameters, and the fact that the centers did not closely approach any of the network of land stations except for a very brief period, the location of the center of the storm was in each case a very unsatisfactory matter.

Porto Rican tropical cyclone of August 22, 1916.

The history of the second tropical cyclone, charted as Low No. XIII, is enveloped in more or less obscurity. Advice of this storm was received from Observer F. E. Hartwell, official in charge, San Juan, P. R., who sent a special observation to the Washington office at 6 a. m., Tuesday, August 22, and later the following report—

Tuesday, 22d.—Hurricane of comparatively small diameter passed over Porto Rico this forenoon, vortex entering the island at about Naguabo and leaving between Arecibo and Isabella. Wind velocity at San Juan 90 miles per hour for about 45 minutes. Highest 10-minute period about 92 miles per hour. Much damage was done throughout the island, a million dollars being a conservative estimate of the money loss. Area of destruction was probably 45 or 50 miles wide and time of passing about two and a quarter hours. The rainfall at San Juan was comparatively light, no excessive falls occurring, and the total was less than 2 inches, but reports of as much as 7 to 9 inches have since been received from the interior of the island.—*F. E. Hartwell, Observer.*

The barogram for San Juan gave no indication of the approach of a disturbance until after midnight of the 21st, when it began to fall slowly. By 6 a. m. of August 22 the pressure was falling quite sharply, the lowest point, 29.44 inches, being reached at 7 a. m. Thereafter the rise was as rapid as the previous fall had been. By 8 o'clock the barometer was practically normal. After leaving Porto Rico on the morning of the 22d, the center of the storm did not approach any of the meteorological stations in the Bahamas or Cuba. Slight indications of its presence northwest of Haiti came to hand; continuous watch on the south Florida coast, while failing to show the presence of a tropical cyclone, did indicate the presence of a feeble disturbance east of the Florida peninsula on the 25th and 26th.

Tropical cyclone of August 28–September 1.

The third tropical cyclone of the month was indicated by cable reports from the Windward Islands on the morning of the 29th, as being south of and near Porto Rico. Mail reports just received show that an intense storm passed over Dominica during the afternoon and evening of the 28th. The hurricane advanced over the island with but little warning; a number of lives were lost and much property was destroyed on the northern and eastern sides.

Mr. W. A. R. Rawle, special meteorological observer at Roseau, furnishes the barogram reproduced as figure 1. Special interest attaches to this barogram, because it is typical of cyclones of extremely small diameter and rapid movement such as passed over Porto Rico, as detailed in the preceding paragraph. After passing to the westward of Jamaica on the 31st this storm was evidently dissipated over the Yucatan peninsula on September 1.

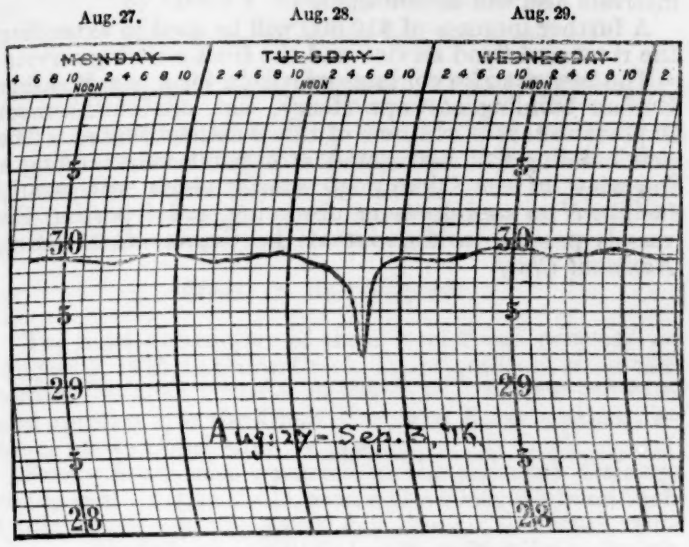

FIG. 1—Barogram at Roseau, Dominica, Aug. 27-29, 1916.

Valuable reports of the cyclone of the 12th–18th were received by wireless from vessels of the United Fruit Co., especially the *Tenadores* and *Turrialba*, the former passing northward over the western Caribbean on the 16th and cutting the path of the hurricane at right angles and slightly to the rear of its center.

DISTRICT WARNINGS DURING AUGUST.

Chicago district.—Frost warnings were issued on the 13th and 27th for the entire cranberry marsh region of Wisconsin; for the marshes in central Wisconsin on the 26th; and on the 11th and 29th for the marshes of northwestern Wisconsin.

Fire-weather warnings for Minnesota were issued on August 9 and 10.—*Chas. L. Mitchell, assistant forecaster.*

Denver district.—The only warning issued during the month was that for frost in high places in Utah on the 18th.—*Frederick W. Brist, Assistant Forecaster.*

New Orleans district.—A small disturbance was central off the mouth of the Rio Grande Valley at 8 p. m. on August 5, and northeast storm warnings were ordered for the Texas coast stations at 8:30 p. m. The storm moved westward into Mexico and its passage was attended by storm winds on the Texas coast.

The only other feature of interest in this district during August was the tropical disturbance which moved inland near Corpus Christi, Tex., on the 18th.

Advisory warnings were received regularly on and after August 13 giving the location, probable intensity, and course of movement of the tropical disturbance.

On August 16 all vessels bound for the Yucatan Channel and Cuban ports were advised to delay sailing on account of the following advisory warning:

Advisory warning, 10 a. m. Tropical disturbance apparently central about 200 miles south of central Cuba, moving west-northwest. Storm is of greater intensity than indicated by earlier reports. It will doubtless reach the Yucatan Channel Thursday. Vessels bound for those waters should exercise caution.—*Henry.*

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Advisory warnings were distributed on the 17th, and vessels were advised to delay sailing until further advised. Up to the night of August 17, 12 vessels, which had cleared from New Orleans, had anchored in the river in the vicinity of Pilottown and 8 to 10 steamers came into the river from the Gulf of Mexico to await further advises from the Weather Bureau, so that about 20 steamers were at anchor waiting for advices that it would be safe to proceed.

On August 18 the following warnings were issued:

Hoist northeast storm warnings, Texas coast, 7:40 a. m. Tropical disturbance probably moving north of west in west Gulf. Increasing winds with northeast gales and high tides to-day and to-night. Vessels bound from New Orleans to Cuban and Central American ports may proceed.—*Cline.*

Change to hurricane warnings 8:30 a. m., Corpus Christi to Brownsville. Center of disturbance as yet probably some distance east of western Texas coast.—*Henry.*

Some of the 20 vessels held at New Orleans would have encountered the hurricane in the Yucatan Channel and might have met the same fate as the *Admiral Clarke*, which was lost on the night of August 16. Vessel masters and agents who held their vessels until the routes were safe express the highest commendation for the manner in which the Weather Bureau kept them advised.—*I. M. Cline, District Forecaster.*

Portland (Oreg.) district.—August was, as usual, a quiet month in this district. Not so much rain fell as usual, but notwithstanding this fact there were few forest fires. No storm or small-craft warnings were issued and none was needed.

Fire-weather warnings were issued on the morning of the 19th, continued on the morning of the 21st, and concluded on the morning of the 23d. This series of fire warnings was the first issued this season; ordinarily it is necessary to issue them early in July.—*E. A. Beals, District Forecaster.*

San Francisco (Cal.) district.—Usually August is a very quiet month in this district and freer from rainy and unsettled weather than any other month. But August, 1916, was notable for the many periods of showery and unsettled weather in all sections. Warnings of showers were issued in southern California for the mountain sections on the 4th, 24th, and 26th, and were verified; but the light showers along the coast on the night of the 23d were not forecast.

In northern California the showers in the San Francisco Bay section on the 14th were not forecast and the warnings issued on the morning of that date were verified only in the mountain sections. The warnings issued on the 27th and 28th were verified in both northern California and Nevada.—*G. H. Willson, District Forecaster.*

A special chart showing the hurricane tracks of the season of 1916 will be published in the December issue of the REVIEW.

EXTENSIONS OF U. S. WEATHER BUREAU SERVICE.

The agricultural appropriation act for the fiscal year ending June 30, 1917, was approved by the President on August 11, 1916. It appropriates $24,948,852 for continuing the work of the department and carrying out new legislation. This is an increase of $1,977,070 over the appropriation for the fiscal year 1916; but this total does not include $600,000 for printing and binding and a number of larger sums for many other specially indicated purposes.

The appropriation for the Weather Bureau is $1,747,260, an increase of $81,210 over the appropriation for 1915–16.

Of this increase $30,000 will be used in extending the weather and storm-warning service in the vicinity of the Panama Canal and various points in the Caribbean Sea and Gulf regions. The number of points from which reports of hurricane conditions are obtained will be increased, thereby making possible the earlier and more complete preparation and dissemination of warnings of the approach of these destructive storms.

The extension of the service, in addition to its value to the residents of the Southern States, it is believed, will be of increasing value to the ships using the Panama Canal. The Weather Bureau also will be able to issue for southern waters, forecasts of general wind and weather conditions and their changes from day to day. These should be of special value to marine commerce passing to and from the canal. These warnings will be transmitted, as in the past, to ships at sea by wireless telegraphy an cooperation with the naval communication stations it Radio, Va., and Key West, Fla.

An increase of $10,000 permits the establishment of additional stations and the better organization of weather observation work in Alaska. Telegraphic observations and reports which have important bearing on the preparation of general weather and storm forecasts for the United States are secured from the region. Additional data to determine and establish the climatic conditions of this great region with its growing agricultural and commercial interests also will be collected.

A further increase of $10,000 will be used in extending the river and flood service and the frost-warning service.

The new act also contains provision for a new Weather Bureau building at Cape Henry, Va., one of the most important coastal stations of the Weather Bureau. The new building will be erected at a point commanding a full view of the fairway of vessels, which will greatly facilitate its usefulness in observing and reporting the vessels passing in and out of the Capes.—*C. C. Clark, Assistant Chief.*

SECTION IV.—RIVERS AND FLOODS.

RIVERS AND FLOODS, AUGUST, 1916.

By ALFRED J. HENRY, Professor in Charge.

[Dated: Weather Bureau, Washington, Sept. 26, 1916.]

A large majority of the floods of record in August, 1916, crested in July, but the river remained above flood stage into the succeeding month. (See tables 2–4). August as a whole was practically free from severe floods in the large streams, although heavy local rains caused destructive floods in certain small streams in West Virginia and the vicinity of Hannibal, Mo.

Floods in West Virginia.

The most destructive of these local floods occurred on August 9, 1916, in Cabin Creek, an insignificant mountain stream less than 20 miles in length that flows northward and empties into the Great Kanawha River a short distance above Charleston, W. Va.

Severe floods also occurred in the adjacent drainage to the west—viz, in Coal Creek, a much larger stream than Cabin Creek—on the same day due to the same rainstorm. Coal Creek is a little less than 60 miles in length rising in Raleigh County and flowing thence northwesterly parallel to the Guyandotte River and emptying into the Great Kanawha a little above Lock No. 7. Little Coal Creek, a tributary of Coal Creek, carries the drainage of the western portion of the watershed directly east of the Guyandotte divide.

No measurements of either rainfall or run-off were made in Cabin Creek watershed. The rainfall was measured at the cooperative station of Madison, Boone County, W. Va., in the watershed of Little Coal Creek and together with that of Charleston and Kanawha Falls, W. Va., both special river stations of the Weather Bureau, are given in the table below.

We are indebted to the United States Engineer officer at Charleston, W. Va., for a copy of the rainfall at Lock No. 2 in the Great Kanawha. These four stations are not far distant from the scene of the floods, but it is quite evident that none of the measurements gives any idea of the amount of the precipitation that occurred directly over the watershed. The cooperative observer at Madison, Mr. S. E. Bradley, states that 6 inches of rain fell at a point 12 miles northwest of his station; also at a point the same distance east.

TABLE 1.—*Precipitation at West Virginia points.*

Stations.	August, 1916.		
	9	10	11
	Ins.	*Ins.*	*Ins.*
Madison	3.20	0	0
Charleston	1.10	0	0
Charleston, Lock No. 2	1.05	0	0
Kanawha Falls	1.50	0	0

The Great Kanawha, as gaged at Charleston, showed a rise of 1.3 feet on the 9th and a further rise of 3.3 feet on the 10th, followed by a fall of 2.5 feet on the 11th. There are no gaging stations on the Great Kanawha between Charleston and its mouth at Point Pleasant, W. Va. The Ohio at the last named point showed a rise of 5.5 feet on the 10th, which may be considered as due to the flood waters in the Great Kanawha.

Cabin Creek, along which the destruction was greatest, is lined with hamlets mainly composed of coal miners' cottages; it was in these hamlets that the greatest loss of life occurred. Press dispatches 3 days after the flood place the loss of life at less than 50, although according to the press dispatches of the day before 60 dead bodies had already been recovered and others were unaccounted for.

Property loss, originally placed at $5,000,000, was reduced by later estimates to $575,000.

Flood in Missouri.

A severe local flood occurred at Hannibal, Mo., about 1:30 o'clock a. m., August 15. The following account has been prepared by Meteorologist B. L. Waldron of the Weather Bureau office at Hannibal, Mo.

The excessive rains of the night of August 14–15 following the heavy rains from the 11th to 13th, in the vicinity of Quincy, Ill., Hannibal and Louisiana, Mo., caused flood conditions in the creeks and the small rivers of this vicinity that resulted in a great amount of damage.

Bear Creek, at Hannibal, overflowed the bottoms from Oakwood nearly to Main Street and it is estimated that nearly 500 people were driven from their homes; many had to be rescued, some in boats. Water came into many houses, probably causing $1,500 damage to furnishings and the cost of cleaning. Most of the damage was from water and mud. The water was not so high and the damage was less than in the flood of July 29, 1910.

The C., B. & Q. R. R. lost bridges and dumps, from below Quincy to Elsberry, Mo., that it will cost $150,000 to replace, and the St. L. & H. R. R. loss will amount to $49,000. More bridges and dumps were washed out in this flood than at any one time in many years.

Train service from Hannibal to St. Louis was suspended from the morning of the 15th to the 20th, though one or more trains were run to Louisiana on the 19th.

In Marion, Monroe, Ralls, and Pike Counties, Mo., much damage was done to highways and bridges.

Other floods.

Flood warnings were issued for the Pecos River of west Texas on the 8th and again on the 23d, and for points on the Arkansas in eastern Colorado on the 21st. Beyond the flooding of bottom lands these floods caused no material damage.

Heavy local rains on the 10th, especially in north-central Illinois, caused washouts on the railroads of that section but the damage was quickly repaired.

Flood losses, August, 1916.

Buildings, railroads, telegraph and telephone lines (West Virginia)	$575,000
Highways and bridges (Hannibal, Mo.)	10,000
Buildings (Hannibal, Mo.)	1,500
Crops, prospective (Hannibal, Mo.)	8,000
Annual rise of Columbia, 1916:	
Railroads, highways, bridges, etc	7,640
Crops, gathered	3,600
Crops, prospective	3,680
Live stock, farm buildings, etc	600
Suspension of business	12,225
Total	622,245

Hydrographs for typical points on several principal rivers are shown on Chart I. The stations selected for charting are Keokuk, St. Louis, Memphis, Vicksburg, and New Orleans, on the Mississippi; Cincinnati and Cairo, on the Ohio; Nashville, on the Cumberland; Johnsonville, on the Tennessee; Kansas City, on the Missouri; Little Rock, on the Arkansas; and Shreveport, on the Red.

TABLE 2.—*Floods in the East Gulf States during August, 1916.*

River.	Station.	Flood stage.	Above flood stage.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
West Pearl	Pearl River, La	12	1	7	14.2	[1]26
Tombigbee	Demopolis, Ala	39	1	2	66.2	[1]16
Flint	Bainbridge, Ga	25			23.9	1
Ocmulgee	Abbeville, Ga	11	1	4	14.1	[1]28
Do	do	11	9	10	11.5	9
Do	Lumber City, Ga	15	1	1	16.2	[1]30
Do	Macon, Ga	18			16.6	3

[1] Occurred in July.

TABLE 3.—*Floods in the South Atlantic States during August, 1916.*

River.	Station.	Flood stage.	Above flood stage.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Edisto	Edisto, S. C.	6	1	3	6.8	[1]31
Saluda	Chappells, S. C.	14			12.4	2
Santee	Rimini, S. C.	12	1	15	35.8	[1]20
Do	Ferguson, S. C.	12	1	19	24.7	[1]22
Black	Kingstree, S. C.	12	1	5	15.5	[1]17
Lynches	Effingham, S. C.	14	1	4	15.0	3
Waccamaw	Conway, S. C.	7	1	14	9.2	1
Cape Fear	Elizabethtown, N. C.	20	1	1	27.4	[1]28

[1] Occurred in July.

TABLE 4.—*Floods in various other rivers during August, 1916.*

River.	Station.	Flood stage.	Above flood stage.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Holston, North Fork	Mendota, Va.	8	16	16	14.0	16
Columbia	Marcus, Wash.	24	1	6	33.8	[1]5
Do	Vancouver, Wash.	15			14.8	1
Willamette	Portland, Oreg.	15			14.3	1

[1] Occurred in July.

FLOODS IN THE EAST GULF AND SOUTH ATLANTIC STATES, JULY, 1916.

By ALFRED J. HENRY, Professor in Charge.

[Dated: River and Flood Division, Weather Bureau, Sept. 20, 1916.]

The immediate cause of the destructive floods in the East Gulf and South Atlantic States was the movement over those States of two tropical cyclones, whose approximate paths are shown in figure 1 (XLIV–93).[1]

The first of these storms passed inland over the Mississippi coast during the night of July 5–6, 1916, and moved slowly a little west of north to about the thirty-second parallel of north latitude, thence it followed a somewhat sinuous course a little east of north for several days, finally by the morning of July 11 it had become a disturbance of such feeble intensity that its future course could not be followed. In its movement over the State, which occupied practically all of five days, rain fell almost continuously; in some parts of the State, as will appear from the daily rainfall charts which accompany this report, figures 3–14 inclusive, the rainfall was extraordinarily heavy. As this storm drifted over northern Alabama and eastern Tennessee its sphere of influence extended across the Appalachians into the Carolinas, the mountain districts of which received heavy rains.

Almost immediately a second tropical cyclone moved in from the Atlantic, passing over the coast of South Carolina on the morning of July 14, 1916. During that day torrential rains fell on the lowlands a short distance northeast of Charleston, attended by high winds. By the morning of the 15th the center of the storm had reached western North Carolina. Beginning in the afternoon of that day and continuing for 24 hours, unprecedented rains fell over the eastern slope of the Blue Ridge and also in the valley of the French Broad as it flows northward between the several parallel ranges of the Blue Ridge. The run-off from these rains by reason of the saturated condition of the soil must have been 80 or 90 per cent of the precipitation. Naturally floods hitherto unprecedented occurred in both the Tennessee and Atlantic drainage, as will appear later in this report.

When tropical cyclones move into extratropical latitudes they generally retain some of the characteristics which differentiate them in the beginning from extratropical cyclones. The precipitation of a tropical cyclone is torrential in character and rather uniformly distributed around the center of the storm. In extratropical cyclones the precipitation is not uniformly distributed about the center, but the maximum amount is generally found over the southeastern quadrant some little distance from the center. A common characteristic of extratropical cyclones is that whenever the rate of progression of the storm is retarded the cumulative precipitation in its path generally exceeds the so-called excessive rate.

Whether the extraordinary rains of the East Gulf and South Atlantic States were due to the fact that tropical storms passed over them, or whether the rains would not have been equally heavy had the storm been of extratropical origin is not a question of material importance. The writer is inclined to the opinion that the distribution of the precipitation in connection with these two storms is such as might be expected from an extratropical cyclone following the identical paths pursued by the tropical cyclones shown on figure 1. This belief is strengthened by the fact that the floods of August, 1908, in South Atlantic States, floods that are generally recognized as being hitherto the most severe of record in those States, were due to a rather feeble extratropical cyclone that advanced slowly from southern Alabama on August 24, 1908, to the Atlantic off Cape Hatteras on August 27.

The record of rainfall in connection with both storms is included in Table 3 and the areal distribution is illustrated in a series of charts, figures 2–17. The scale of the charts is about 110.5 miles to an inch. It is a matter of regret that it was not possible to present charts on a much larger scale. A casual inspection of these charts will show that during the early period of both storms there were isolated areas, or islands, of exceptionally heavy rains within a general area of moderate rains. Such islands appear on the chart for the 6th, figure 3 for example, in southeastern Mississippi, south-central Alabama, and extreme northwestern Florida. The island in southeastern Mississippi is the greatest in superficial extent, covering parts, if not all of the counties of George, Perry, Greene, and Jones in Mississippi, and portions of Washington and Mobile Counties in Alabama.

[1] Accompanied by Charts XLIV–93 to XLIV–110, presenting figures A. J. H. 1–20.

Figure 2 is a special chart prepared to illustrate on a scale of about 35 miles to the inch the distribution of precipitation for the 4 days, July 5–8, 1916, in southeastern Mississippi. That portion of the State is well covered with rainfall stations and the delineation of the areas of heavy precipitation is not difficult. Across the border in Alabama the reporting stations are not nearly so numerous; such as are available, however, show that the intensity of the rains rapidly diminished with distance from the border (see the small scale maps, figs. 3, 4, and 5). The center of the cyclone on the 6th was northwest of the island of heavy precipitation in southeastern Mississippi and distant therefrom not more than 100 miles. No explanation is at hand as to the cause of these three separate and apparently distinct regions of heavy precipitation separated from each other by regions of lesser precipitation. In this connection it is interesting to note that previous torrential rains in southeastern Mississippi generally have been associated with extra-tropical cyclones and that the month of greatest frequency appears to be April.

The record flood in the rivers of eastern Mississippi occurred in April, 1900, and was due to a period of about 60 consecutive hours of rain. Some of the 24-hour amounts in April, 1900, are Bay St. Louis, 8.77 inches; Canton, 5.25 inches; Natchez, 6.75 inches; Port Gibson, 7.64 inches; Meridian, 6.85 inches. At the last-named station 10.57 inches of rain fell from 12:50 p. m., April 15, to 8:10 a. m., April 17, 1900, a period of 43 hours and 20 minutes. These long-continued rains were due to the presence of an extra-tropical cyclone in northern Oklahoma and its slow movement thence to the upper Lake region. The movement of that cyclone as indicated induced southeast winds over Mississippi and adjoining States. In a general way the rainfall diminishes with distance from the coast line, but there are notable exceptions that lead us to conclude that distance from the coast line is not the controlling factor. In the heavy rains of April, 1900, and again in July, 1916, the islands of heavy rainfall were situated not on the coast but some little distance inland. During the continuance of the heavy rains in George, Greene, and Jones counties, Miss., in July, 1916, the rainfall along the Gulf coast not more than 50 miles distant was less than half as much, the average of three stations being 4.92 inches.

On the succeeding day, July 7, the center of the cyclone advanced about 50 miles in an east-by-north direction. On this day heavy rains fell over the watershed of the Black Warrior River with southeast to south winds; the greatest 24-hour precipitation, 11.2 inches, occurred, however, in the Coosa River watershed at Clanton in Chilton County a little to the southeast. Goodwater in the adjoining county to the eastward also recorded heavy precipitation, thus establishing a second area of heavy rains to the southeast of the storm center.

On the following day, July 8, with the storm center apparently over west-central Alabama, a fairly large area of 24-hour rains in excess of 8 inches (8 to 12 inches), is noted over southeastern Alabama and in the lower Chattahoochee watershed. Some of the recorded amounts are: Alaga, Ala., 12.7 inches; Eufala, Ala., 10.8 inches; Ozark, Ala., 9.0 inches; Blakely, Ga., 9.9 inches; Fort Gaines, Ga., 9.0 inches; and De Funiak Springs, Fla., 10.8 inches. (See fig. 5.) Roughly the area covered by a rainfall of 8 inches and over was about 4,945 square miles and by the area of 4 inches and over was about 17,582 square miles.

On the succeeding day, July 9, the rains diminished in intensity over Alabama and low-lying regions but a considerable increase was noted in the mountain districts of the southern Appalachians. With the gradual filling up of the cyclone that was the original cause of the rains, the amounts which fell on the 10th were not sufficient in themselves to cause floods but they served to saturate the soil and to keep the streams at moderately high stages and thus to prepare the way for serious floods as soon as the downpour of the second storm was precipitated upon them.

This storm like its predecessor was presumably of tropical origin, although but little information as to the position of its origin is available. It passed inland close to Charleston, S. C., on the morning of July 14, 1916, moved thence slowly northeastward and dissipated over the mountains of western North Carolina on the 16th.

The rainfall of this storm also was irregularly distributed about the storm center. On the 14th heavy rains fell northwest of Charleston in Berkeley, Georgetown, and Dillon counties. (See Table 1 and the record for Pinapolis, Oaks, and Dillon, S. C.) The fall in Dillon County was not so heavy as in Berkeley County. On the succeeding day, July 15, when the storm center was over the mountainous region of western North Carolina, heavy rains continued over the low-lying regions of the northeastern part of South Carolina, especially in the line of counties along the right bank of the Great Pee Dee River—viz, from north to south, Chesterfield, Darlington, Florence, and Williamsburg (see the rainfall map of July 14, fig. 12). On this same date, 14th, heavy rains, 8 to 10 inches, were also recorded in western North Carolina at five stations. The climax in the intensity of the rains was not reached until two days later on July 16, at a time when the cyclonic disturbance was not noticeable on the daily maps of the Weather Bureau.

Beginning during the afternoon of the 15th and continuing for 24 hours the rains in the mountain districts of North Carolina were extraordinarily heavy. At a special orchard station maintained at Altapass in the southeastern corner of Mitchell County, N. C. (altitude 2,625 feet above mean sealevel), an actual measurement of 19.32 inches of rain in 24 hours was recorded in an 8-inch standard raingage. The measurement was made at 6 p. m., July 16, 1916. According to the observer, Mr. J. S. Bowen, between 2 p. m. Saturday and 2 p. m. Sunday, 16th, the rainfall here amounted to 19.32 inches as measured on the 16th, and about 2.90 inches of the rainfall measured on the afternoon of the 15th fell after 2 p. m. of that day, hence the 24-hour rainfall, 2 p. m. 15th until 2 p. m. the 16th, was about 22.22 inches. The environment of this station is as follows:[2]

> The station at Altapass is at the head of a ravine about 8 miles in length that leads west of north over a gap in the main range of the Blue Ridge Mountains. The gage is on the main semicircular slope and about 300 feet below the crest of the gap. The ravine is several miles in width at the base but gradually narrows to less than a half mile at the crest. This gap is the dividing line of the watershed of the Catawba (Santee) and the North Toe (Tennessee) Rivers. The general direction of the range is from northeast to northwest, but at this point it forms a semicircle facing south-southeast. The altitude increases in both directions to such mountains as Grandfather (5,964 feet), at a distance of 10 miles to the northeast, and to Mount Mitchell (6,711 feet), about 15 or 20 miles to the southwest.

The rainfall at Altapass Inn, about 1 mile from the orchard station and on the west side of the gap at about the same elevation, was also measured, the amount being 1.52 inches less than on the east side of the gap. Twenty miles to the westward, as at Cane River, Yancey County (elevation unknown), the 48-hour fall diminished to 3.32 inches, as compared with 23.22 inches at Altapass. Total

[2] Manuscript report of Meteorologist L. A. Denson.

24-hour falls of more than 10 inches were recorded in the extreme western portion of Caldwell County on the eastern slope of the Blue Ridge, about 15 miles distant from Altapass. Torrential rains also fell in Avery County, immediately west of Caldwell County, and a second area of torrential rains is noted in western North Carolina; in the watershed of the French Broad at the stations of Blantyre, Brevard, and Hendersonville; in Transylvania and Henderson Counties; also in Macon County, in the extreme southwestern part of the State, where 9.92 inches were recorded at Highlands. It therefore appears that there were two distinct regions of torrential rains in western North Carolina on the 15th–16th—one in Mitchell, Avery, and Caldwell counties, about 50 miles northeast of Asheville, the other about 20 miles due south of Asheville in Henderson and Transylvania counties.

The precipitation after the 16th was insignificant.

HOURLY PRECIPITATION.

Automatic records of hourly precipitation are available only for the principal stations of the Weather Bureau. We have tabulated the hourly values for Mobile, Montgomery, and Birmingham, Ala.; Meridian, Miss.; Atlanta, Ga.; Chattanooga, Tenn.; and Asheville, N. C., for July 5–9, both inclusive, and present them in Table 2. These records show, as was to be expected, varying intensities of rainfall for different portions of the storm and for different portions of the same 24 hours; thus at Mobile, Ala., heavy rain began 10:11 p. m. of the 5th, increased in intensity until midnight, and then diminished, ceasing at 2 p. m. of the 6th; rain began again between 4 and 5 a. m., July 7, and continued at a moderate rate until between noon and 1 p. m., when the intensity suddenly increased to a maximum of 2.67 inches between the hours of 1 and 2 p. m. The details of this excessive rate follow:

TABLE 1.—*Excessive precipitation at Mobile, Ala., July 8, 1916, 12:40 to 1:50 p. m.*

Five minutes ending—	Accumulated amounts.	Actual 5-minute amounts.	Five minutes ending—	Accumulated amounts.	Actual 5-minute amounts.
	Inches.	*Inches.*		*Inches.*	*Inches.*
12:40 p. m.	0.12	0.12	1:20	1.57	0.32
12:45	0.17	0.05	1:25	1.88	0.31
12:50	0.29	0.12	1:30	2.42	0.54
12:55	0.42	0.13	1:35	2.85	0.43
1:00	0.49	0.07	1:40	2.92	0.07
1:05	0.68	0.19	1:45	3.02	0.10
1:10	0.93	0.25	1:50	3.09	0.07
1:15	1.25	0.32			

The period of maximum intensity was from 1:10 to 1:35 p. m., when 2.17 inches of rain fell, or at the rate of 5.21 inches per hour. The above appears to be the greatest fall for 25 minutes in August as far as the records of automatic gages are concerned. An eye observation of a fall of 2.12 inches in 20 minutes at Jupiter, Fla., on August 21, 1893, or at the rate of 6.36 inches per hour, is probably the greatest fall of record for 20 minutes in August.

TABLE 2.—*Hourly rainfalls at seven selected stations in the southeast, July 5 to July 9, 1916, inclusive.*

July 5.

Stations.	A. M.												P. M.												Total 24 hours.
	1	2	3	4	5	6	7	8	9	10	11	Noon.	1	2	3	4	5	6	7	8	9	10	11	Mid-night.	
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
Mobile					T.	T.	0.02	0.05	0.13	0.18	0.20	0.42	0.24	0.46	0.12	0.16	0.30	0.32	0.33	0.34	0.51	0.51	0.63	0.90	5.82
Montgomery												T.	T.	T.	T.	T.	T.	T.	T.	T.	.04	.02	.02	.05	0.13
Meridian													T.					T.	.04	.03	.09	.12	.02	.16	0.46
Birmingham													T.	.01						T.	T.	.05	.20	T.	0.26
Atlanta													.10	.03	.06						T.				0.19
Chattanooga																									0.90
Asheville																									

July 6.

Mobile	0.75	0.13	0.10	0.15	0.15	0.19	0.05	0.34	0.20	0.54	0.12	0.01	T.	0.01											2.74
Montgomery	.07	.14	.15	.12	.16	.13	.22	.14	.16	.33	.64	.25	0.17	.76	0.20	0.27	0.03	0.27	0.16	0.29	0.11	0.05	0.18	0.66	5.66
Meridian	.09	.11	.24	.51	.19	.60	.36	.33	.21	.08	.09	.25	.36	.19	.21	.77	.48	.13	.09	.05	.22	.21	.33	.10	6.20
Birmingham	.02	.06	.08	.03	.02	.03	.06	.01	.12	.23	.44	.72	.33	.53	.29	.22	.13	.03	.21	.15	.25	.14	.16	.32	4.58
Atlanta							T.		.03	.08	.07	T.	.02	.01	.01	T.	.18	.05	.16	.02	.01	.05	.05	.01	0.75
Chattanooga															T.	.01			.01	T.	T.	T.	T.	.04	0.06
Asheville																									0.00

July 7.

Mobile					0.03	0.06	0.09	0.24	0.30	0.16	0.37	0.16	0.57	2.67	0.09	T.	T.	0.11	0.14	T.					4.99
Montgomery	0.11	0.05	0.05	0.03	.01	.08	.09	.10	.03	.06	.15	.82	.13	.32	.13	0.02	0.06	.07	.02	0.01	T.	T.	0.01	T.	2.35
Meridian	.23	.02	.18	.02	T.		T.	.03	.08	.46		T.	T.			.02	.01	.02	.01	.01	T.	T.	T.	T.	1.09
Birmingham	.41	.08	.44	.41	.34	.53	.23	.14	.74	1.15	.77	.05	.07	.19	.16	.08	T.	.04	.07	.16	0.06	0.23	.29	0.38	7.02
Atlanta	.01	.01	.06	.01	.04	.02	.04	.24	.27	.54	.24	.06	.12	.13	.06	.13	.52	.11	.02	.03	.02	.10	.11	.09	2.98
Chattanooga	.04	.04	.05	.06	.01	.02	.03	.06	.04	.12	.25	.10	.07	.13	.06	.07	.03	.02	.06	.11	.09	.04	.01	.05	1.56
Asheville														T.	.09	T.	T.	.01							0.10

July 8.

Mobile						T.									0.04	0.30									0.34
Montgomery	T.	T.																	0.16	T.	0.07	0.03	0.16	0.36	0.78
Meridian	T.	T.	T.	T.	0.01	T.	T.	T.	T.	T.	T.	T.	0.13	0.01	.03	.06	0.04	T.							0.28
Birmingham	0.14	0.02	0.01	0.18	.03	0.02	0.02	T.	0.01	T.	0.02	0.02	.02	.01	.01	T.	T.	0.04	.04	T.	.04	.04	T.	T.	0.67
Atlanta	.15	.17	.20	.23	.03	.16	.09	T.	.06	0.08		T.	.02	.04	.01		.02	.13	.01	0.01	.10	.18	.08	.10	1.87
Chattanooga	.25	.20	.21	.26	.31	.43	.26	0.25	.41	.23	.11	.11	.24	.09	.02	.28	.12	.32	.31	.12	.18	.04	.07	.02	4.84
Asheville								.01	.14	.10	.09	.11	.10	.12	.22	.06	.14	.35	.03	.06	.20	.08	.12	.15	2.08

July 9.

Mobile	T.																								T.
Montgomery	0.28	0.07	0.02	T.	0.01	T.	0.03	T.	0.01	T.	T.	T.	T.	T.	T.	T.	T.								0.42
Meridian																			T.	T.					T.
Birmingham	.02	.02	.01	0.03	.01	0.02	.02	0.01	T.	T.	0.01	0.01	0.01	0.01	0.01	T.	T.	0.01	0.01		0.02	0.11	0.07	0.12	0.53
Atlanta	.65	.38	.14	T.	.07	.01	.05	.10	.03	0.04			.04	.01	.02	0.03	0.01	.04	.07	T.					1.69
Chattanooga	.01	.19	.12	.01	.14	.07	.14	.31	.02	.03	.06	.10	.54	.05	.54	.15	T.	.06	.13	0.01	.02	.01	.02	01	2.74
Asheville	.18	T.	.04	.06	.02	T.	T.	T.	T.	.04	.14	.05	.01	.29	.04	.07	.02	.08	.03	.02	.04	.04	.03	.01	1.21

CUMULATIVE PRECIPITATION.

In figure 20 will be found curves showing for 5 stations the cumulative precipitation during the continuance of the storm. In the last curve of the diagram, reading from left to right, that for Blowing Rock, N. C., the cumulative precipitation for both storms is given. The rains of the 8th in western North Carolina were light. On the 9th and 10th they were uniformly heavy; and again on the 15th and 16th as graphically shown in the diagram. It was only in western North Carolina that the severity of the floods was markedly increased by the sequence of the rains. River stages in the watersheds given on the diagram will be found in Table 4 and hydrographs in figures 18 and 19.

FLOODS IN THE RIVERS OF MISSISSIPPI AND ALABAMA.

The rains in the East Gulf States began along the coast of Alabama and Mississippi on July 5 and advanced to the northern parts of those States by the night of July 6, the heaviest rains falling on the 6th, 7th, 8th, and 9th. While there were some scattered heavy rains on the 10th, those in Alabama and Mississippi were mostly light after the 9th. (See the rainfall maps, figs. 3–11.)

When the rains began the rivers were at low stages and the ground was moderately dry, although there had been intermittent thundershowers during the 10 days previous.

The rains, it may be remembered, began first over the lower reaches of the rivers and progressed toward the headwaters of the streams. The run-off where the rainfall was heavy reached the streams almost immediately, and we have the rather anomalous situation of a river being in flood in its lower reaches before the headwaters have reached the flood stage. Thus the Pascagoula at Merrill, Miss., as a result of the heavy rains on the 6th (over 12 inches) reached the flood stage on the 7th although the crest stage at the next up-river station was not attained until three days later. In the region of heavy rains and consequently high run-off the first effect of the rains was a sudden and very marked rise, followed by a slight fall, and then a second and longer rise. The flood stage was naturally long drawn out by reason of the advance of the rains in a direction directly opposite to that of the course of the streams.

The Black Warrior River at Tuscaloosa crested at 66.3 feet at about 6 p. m. of the 8th and continued above the flood stage until the 16th; it was again in flood on the 20th and the 21st.

The Tombigbee reached flood stage at the uppermost gaging station on the river, Aberdeen, Miss., on the 11th and at Demopolis, Ala., the lowermost station, 4 days later.

The two main tributaries of the Alabama River—the Coosa and the Tallapoosa—crested at different times owing to the rainfall distribution in their respective watersheds. The Tallapoosa, at Millstead, Ala., barely reached the flood stage on the 9th, while the Coosa crested at Wetumpka two days earlier and at Rome, Ga., 3 days later. The failure of the floods on these two rivers to synchronize operated to diminish the flood wave on the Alabama. As a result the latter was a long drawn out swell. (See the hydrograph for Selma, fig. 18.)

The fluctuations of the Coosa River at Wetumpka, Ala., were unusual. On the morning of the 7th the 24-hour rise was 23.8 feet; in the succeeding 24 hours it rose 23.4 feet, bringing the stage up to 51.4 feet at 7 a. m., July 8. It then rose slowly to a crest of 51.5 at 3 p. m. of the 8th and then began to fall, reaching a stage of 49 feet on the afternoon of the 9th; it then began to rise again and reached a second crest of 51.3 feet at 3 p. m. of the 11th. These irregular fluctuations may be due in part to the manipulation of the floodgates at the Alabama Power Co.'s plant at lock No. 12 on the Coosa River.

Overflow in Alabama and Mississippi.—An attempt has been made to show the areas of overflowed lands along the rivers of the East Gulf and South Atlantic States. (See fig. 1.) By reason of the small scale of the map these areas must be considered as approximate only.

The Pascagoula River from Merrill, Miss., to the coast overflowed its banks on an average about 3 miles on each side of the river and in places to a greater extent. In the counties of Wayne, Jones, Forrest, Perry, Greene, George, Pearl River, Hancock, Harrison, and Jackson much damage was sustained by high winds as well as by heavy rains and overflow.

The lowlands for 90 miles along the Black Warrior between Tuscaloosa and Demopolis, Ala., and along the Tombigbee for 170 miles below the last-named place were inundated on an average at least 1¼ miles on each side of the river.

Mr. P. H. Smythe, section director of Alabama, estimates that 350,000 acres of land in that State were overflowed, with a total loss of all crops thereon.

The rivers of Georgia at the beginning of the rains were at the usual low stages of midsummer. The slow movement of the tropical cyclone and the continued rains of the 5th and 6th started a moderate flood stage in the upper reaches of the Chattahoochee on the 8th, and this was followed by a second moderate flood wave on the 10th. Along the middle stretches of the stream, as at Columbus, Ga., and Eufala, Ala., the rains culminated on the 8th in tremendous downpours; 12.7 inches fell at Alaga, Ala., 10.8 inches at Eufala, Ala., 9.9 inches at Blakely, Ga., and 9 inches at Fort Gaines, Ga. The river at Eufala responded immediately by a rise of 38.8 feet, viz, from 3.8 feet on the 7th to 42.6 feet on the morning of the 8th. The flood wave coming down the river did not reach Eufala until the next day, when an additional rise of 7.4 feet was recorded. The Flint River was also in flood, but not to the same extent as the Chattahoochee, and this is also true of the other large rivers of Georgia—the Ocmulgee, Oconee, Altamaha, and the Savannah.

Floods in the rivers of South Carolina.—The rains that attended the first storm did not begin over South Carolina until the 8th (see Table 1) and were not specially heavy, except over the mountain headwaters in North Carolina. The effect of these rains, however, was to saturate the soil and cause freshet stages on all the streams. These freshets had begun to decline when the second storm with its attendant rainfall overspread the State. The heavy rains of the second storm began over the watersheds of the Black, Lynches, and Great Pee Dee Rivers in the lowlands of the State and at a time when these rivers were comparatively low. Fortunately, the rains of the first, or Alabama, storm were not heavy over the lowlands of the Carolinas. The rise of the Black, the Lynches, and the Great Pee Dee is shown by the hydrographs on figure 19.

As the second storm moved inland over South Carolina on the 15th, heavy rains fell, beginning on the afternoon of that date and continuing for about 24 hours. It was to these rains that the disastrous floods in the upper tributaries of the Santee were due. On the 16th the Catawba at Mount Holly, N. C., had reached a stage of 3.5 feet above the previous highest record. On the

17th the flood crested at a stage of 45.5 feet (estimated, the gage having been washed away). That stage is 22.5 feet above the previous high-water mark.

The Catawba rises in North Carolina in the counties of Caldwell, Burke, McDowell, and Avery directly east of the Blue Ridge and at an elevation of about 2,500 feet. It flows thence southeasterly as the Catawba in North Carolina and as the Wateree in South Carolina, forming with the Congaree the Santee. The gradient of the upper part of the Catawba is steep, its profile showing a fall of about 2,325 feet in the 200 miles between headwaters and Camden, S. C.[3] At the last-named point the zero of the gage is 175 feet above mean sea level. At the junction of the Wateree and the Congaree the water surface is probably not more than 100 feet above mean sea level. The steep gradient above "the fall line"[4] is a characteristic of all rivers of South Carolina, except the Little Pee Dee, Waccamaw, Lynches, Combahee, Edisto, and Black, which rise wholly within the Coastal Plain and flow directly into the Atlantic. The flood on the Catawba in North Carolina is perhaps the most severe of which there is record. At Mount Holly, N. C., the uppermost gaging station on the river, the crest was 22.5 feet above the previous high-water mark, viz, that of the 1908 flood. The excess of the next down-river station, Catawba, S. C., just inside the South Carolina border, was but 12 feet, and still farther down and about 200 miles from the headwaters an excess of but 3 feet above the 1908 crest was noted. The force of the current greatly abraded the banks of the stream, the width of which at moderate stages is now 50 feet greater than formerly, as determined by a recent inspection of three points, viz, Mount Holly, N. C., and Catawba and Camden, S. C. The lateral corrasion of the channel thus observed must have been due to the great increase both in the velocity of the stream and the load which it carried. It would be interesting to know in this connection to what extent vertical corrasion was effective in deepening the channel at the time the banks were so greatly abraded.

It is a notable fact that in no other part of the United States are the forces of landscape sculpturing so active and effective as in the South Atlantic States, mainly because those regions more than others are subject to heavy precipitation and consequently frequent floods. Nowhere in the United States, so far as known to the writer, are the streams subject to such frequent and marked changes in volume and in the degree to which they are loaded as in those which have their source in the southern Appalachians.

The Broad River at Blairs, S. C., exceeded the previous high-water mark by 5.4 feet. The Santee at Rimini, S. C., exceeded the previous high-water mark by 2.2 feet; at Ferguson by 1 foot. The Black at Kingstree, S. C., exceeded the previous high-water mark by 1 foot.

The three main tributaries of the Santee which rise in the southern Appalachians are the Saluda, the Broad, and the Wateree, naming them in order from west to east. That one farthest west, the Saluda, was not in extraordinary flood since its watershed was a little outside the region of heavy rains.

The rivers of South Carolina in their course to the sea pass through great swamps in the Coastal Plain. In times of flood vast quantities of water are impounded in these swamps. This explains in a way the flattening out of the flood crest as it passes to the lower reaches of the streams. It will be noted that at Ferguson, the lowermost station on the Santee, the excess of the 1916 flood over previous floods was only 1 foot, notwithstanding the great volume of the flood flow in the upper tributaries.

There was a freshet in the Great Peedee, the farthest east of the larger rivers of South Carolina, on July 6 and again on the 12th. The stage at Cheraw, S. C., on the 15th was about 9 feet below flood. From this point it rose to 6 feet above flood on the morning of the 16th and crested at 36.1, or 9.1 feet above flood stage, on the 19th.

Rivers of North Carolina.—The floods in the rivers of North Carolina which drain into the Atlantic were not severe except in the upper reaches of the Great Peedee (Yadkin).

West of the Blue Ridge all the streams flowing into the Tennessee were in severe flood, probably the most disastrous so far as loss of life and property is concerned being in the French Broad. Gagings in that river are made at Asheville, N. C. On the morning of the 9th the river had reached a stage of 4.8 feet (flood stage, 4 feet), and by the morning of the 11th it had risen to a stage of 8.8 feet; it then declined until the morning of the 15th, when it stood at exactly 4 feet, or flood stage. The tremendous rains on the 15th–16th in the watershed of the river caused it to rise with great rapidity. At 8 a. m. on the 16th it stood at 13.5 feet, 9.5 feet above flood; by 9 a. m of the same day it had risen to 18.6 feet; and at 10 a. m. the bridge on which the gage was located was washed away. The crest of the flood was about 21 feet; the exact figures will be determined later. The width of the French Broad at Asheville at bankful stage (4.4 feet) is 381 feet. At the time of the flood the width of the stream was said to have been a quarter of a mile. All industrial plants along the river were badly flooded, in some cases the water reaching the second stories of the buildings. The flood waters from the upper tributaries of the Tennessee made but a brief flood in the trunk stream at Knoxville about 149 miles below Asheville, where a crest stage of 30.2 feet, 18 feet above flood, was reached at noon of the 18th. At Chattanooga, about 180 miles below Knoxville, the crest was reached two days later, viz, on the 20th, with a gage reading of 30.2 feet, 2.8 feet below flood. Flood stages on the Tennessee below Chattanooga had been reached earlier in the month, but the flow from the upper tributaries due to the torrential rains of the 15th–16th did not cause a flood stage in the main river below Knoxville, and at the latter place for a little less than three days only.

Flood in New River.—The area of heavy rains in North Carolina embraced portions of the watershed of the New or Great Kanawha River. This region (see Table 3, North Carolina) received heavy rains beginning on July 9 and culminating on July 16. On the last-named date New River crested at Radford, Va., at 32 feet (estimated, gage being washed away), 18 feet above flood stage. When this flood reached the lower part of the Great Kanawha it had diminished to about a freshet stage, there being no supporting flood flows in the lower part of the basin.

Daily river stages during the continuance of the flood are given in Table 4.

PREVIOUS FLOODS.

A writer in the Columbia State for Aug. —, 1916, Mr. W. P. Houseal, is authority for the statement that in 1796 a storm passed inland and, crossing the Blue Ridge, created great

[3] A survey of the Catawba River from the Halltown Road crossing, near Marion, N. C., to the mouth of Johnsons Mill Creek, a distance of 45 miles, gives a total fall in that distance of 243 feet (U. S. Geol. Survey, Water Supply Paper No. 115).

[4] A line closely agreeing with the geologic boundary between two geologic formations and characterized by falls and steep rapids in those streams that cross it. In a general way it may be said to bound two topographic provinces of the State, viz, the Coastal Plain and the Piedmont Plateau. (See Maryland Weather Service, Baltimore, 1899, v. 1, pp. 102, 116, and pl. III.)

havoc in the Broad and Saluda Valleys; also that 56 years later—viz, in 1852—a second storm following the same path caused great destruction, especially to the Columbia & Greenville Railway, which had then been in operation only a few years. The same writer refers to three freshets intervening between 1852 and 1908—viz, the so-called Sherman's flood of 1865, a freshet in May, 1886, and in September, 1888. The Weather Bureau records confirm the account of freshets of May, 1886, and September, 1888, and also contain mention of a freshet in 1840, said to have been 15 inches lower than the flood of September 11, 1888. Inasmuch as the crest of the latter at Augusta, Ga., was 38.7 feet, the 1840 flood must have reached a stage of 37.5 feet.[5] The order of magnitude of the floods in the Savannah at Augusta is probably as follows:

	Feet.
First, August, 1908	38.8
Second, September, 1888	38.7
Third, ——, 1840	37.5
Fourth, March, 1912	36.8

The crest of the 1916 flood at Augusta was but 28.4 feet on the 12th, 3.6 feet below flood stage. The headwaters of the Savannah were outside the region of heavy rains on the 15th and 16th, and consequently the river did not reach the flood stage. This fact illustrates the error inherent in an attempt to pass from great rainstorms to great floods, and vice versa, using the record of a single river only.

Previous floods in the Catawba, of which there is a printed record,[6] occurred in May and June, 1901. A maximum discharge of 150,825 cubic feet per second, or more than 50 cubic feet per second per square mile of drainage area, was recorded in this flood near Rock Hill, S. C.[7]

LOSS OF LIFE AND PROPERTY.

The precise number of persons who lost their lives in the floods will doubtless never be known, although the best information at hand places the loss of life at about 80, the great majority of whom were drowned in the streams of western North Carolina. Eighteen persons went down with the Southern Railway bridge at Belmont, N. C., on July 16, and the majority of these were lost. There was also some loss of life along the Gulf coast during the prevalence of hurricane winds, but these have not been included in the above number. The property loss, as closely as can be figured, was near $22,000,000, distributed as follows:

Tangible property, buildings, roads, bridges, culverts, etc.	$4,917,574
Crops not gathered	11,606,128
Live stock and movable farm property	811,513
Suspension of business, loss of wages, etc	1,938,870
Railroads, in roadbed, bridges, trestles, culverts, etc.	[8] 2,450,000
Total	21,724,085

Thus it is seen that by far the greater loss falls upon the agriculture of the region. The figures are probably incomplete and at best should be considered as rough approximations to the truth.

The loss of crops was due in some cases to hurricane winds which swept over southeastern Mississippi and southern Alabama, attended by heavy rains; in the greater number of cases, however, the loss of crops was due to flooding, especially along the Cahaba and Alabama Rivers in the counties of Perry, Dallas, Wilcox, and Monroe, Ala. In these counties approximately 250,000 acres of farm lands were inundated for several days, with a total loss of all crops thereon. The loss in these counties alone, figuring it at $10 per acre, a not unreasonable figure, approached two and one-half million dollars.

It is reported that in the counties of Greene, Perry, Forrest, George, Jackson, and Harrison, Miss., the loss to standing timber that was leveled by hurricane winds will approach $3,000,000. These figures have not been included in the aggregate above given, since a portion of the timber may be recovered.

In a few cases heavy loss by erosion has been reported, but it is believed that the gain from a deposit of silt, which must have been very general in the lower reaches of streams in the East Gulf States, will offset the losses by erosion.

That agricultural interests have suffered greatly cannot be doubted for a moment, although to what extent in some regions is problematical. The regions most affected by heavy rains and strong winds were southeastern Mississippi, a large part of central and southern Alabama, and parts of South Carolina directly northeast of Charleston, extending thence through the line of counties on the west bank of the Great Pee Dee to the North Carolina border.

The damage in western North Carolina was largely confined to railroads, both steam and electric, industrial plants, public-service organizations, including water, power installation and other industrial enterprises.

Too much credit can not be given the railroads in their effort to reestablish and maintain transportation routes in the face of grave difficulties. In a number of cases the only possible solution of the problem was a resort to the methods of primitive people, viz, the ferry operated by man power. Within a week, or 10 days at the utmost, travel was restored in a limited way, of course, between all important points.

An interesting phase of the subject is the probability of the occurrence of a similar disaster in the future. Unfortunately, our present knowledge of the underlying causes of cyclonic storms, their distribution in time and space, is so indefinite that any discussion thereon must be largely speculative. It may be said, however, that the floods in Mississippi, Alabama, and Georgia were due almost wholly to a single long-continued rainstorm which was closely associated with the passage inland of a tropical cyclone. Likewise, the floods of the rivers in the coastal plain of South Carolina, especially the Great Pee Dee, were due to the movement inland of a single tropical cyclone. The floods in the streams originating in North Carolina were due to the torrential rains of the 15th and 16th coming at the close of a period of heavy rains that were associated with the first or Alabama storm. Tropical cyclones do not, as a rule, synchronize as did these two, and on that fact we would base our belief that a repetition of the storms of July, 1916, is not probable more than once in a century at least.

[5] The crest of this flood is given as 37.3 feet in Report U. S. Chief of Engineers, 1888, pt. 2, p. 1026.
[6] Engineering News, New York, Aug. 7, 1902.
[7] *U. S. Geological Survey*, Water Supply Paper No. 83. Washington, 1903.
[8] Incomplete reports.

TABLE No. 3.—*Daily precipitation, in inches and hundredths, July 5–18, 1916, inclusive.*

State and station.	Watershed.	July, 1916.															
		5	6	7	8	9	10	11	12	13	Total, 5–13.	14	15	16	17	18	Total, 14–18.
Mississippi—		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Louisville	Pearl	.....	2.25	3.09	0.47	0.45	0.13	0.90	1.05	0.00	8.34	0.14	0.00	0.20	0.14	1.00	1.48
Edinburg [1]	....do	.....	0.74	4.64	0.55	0.47	0.10	0.10	0.29	0.15	7.04	0	1.62	0.10	0.03	T.	1.75
Kosciusko [1]	....do	.....	0.52	2.25	1.03	0.30	0.04	0.30	0.33	0.02	4.79	0	0.03	0	0.12	0.01	0.16
Lake [1]	....do	.....	1.15	2.90	0.20	0.05	0	0	0.25	0	4.55	0	0.30	0	0.02	0	0.32
Jackson	....do	.....	1.58	0.25	0.11	T.	0	0.24	0.09	0	2.27	0	0	0.41	0.99	0.01	1.41
Crystal Springs [1]	....do	.....	1.65	2.60	0.35	0.05	0	0	0	0	4.65	0	0	0	0.25	0	0.25
Hazlehurst [1]	....do	.....	1.20	2.90	0.35	0.16	0	0	0.06	0	4.67	0	0	0	3.10	0.02	3.12
Brookhaven [1]	....do	.....	0.91	2.08	0.03	0.02	T.	T.	0.12	0	3.16	0	0	1.13	0.09	1.70	2.92
Monticello	....do	.....	2.25	0.40	0.12	0	0.03	0.08	0	0	2.88	0	0	0	0.77	0	0.77
Magnolia	....do	.....	1.25	T.	T.	0	0	0	0	0	1.25	0	0.18	0	T.	0.22	0.40
Columbia [1]	....do	.....	1.85	1.33	T.	0	0	0	T.	0	3.18	0	0	0.77	0	0.50	1.27
McNeil	....do	.....	2.00	9.85	0.02	0.04	0.62	0.65	0	0	13.18	0	0.30	0	0	1.28	1.58
Pearlington	....do	.....	1.16	0.64	0.41	0	0	1.86	0	0	4.07	0	0.18	0	0.90	0.62	1.70
Meridian [2]	Chickasawhay	.....	6.20	1.09	0.28	T.	0.02	0.93	0.08	T.	8.60	T.	0	T.	0.98	0.77	1.75
Hickory	....do	.....	4.52	3.06	0.40	0	0.11	0.21	0.43	0	8.73	0	0.18	0	0.07	0.08	0.33
Enterprise [1]	....do	.....	3.02	4.65	0.18	0.10	0.08	0	0	0	8.03	0.10	0.36	0	0	0.38	0.84
Shubuta [1]	....do	.....	4.95	3.95	0.20	0.15	T.	0	0.15	0	9.40	0	0.25	0	T.	T.	0.25
Waynesboro [1]	....do	.....	5.60	6.20	1.00	0.12	T.	0	0.85	0.18	13.95	0.18	0.60	0	0	T.	0.78
Leakesville [1]	....do	.....	10.00	6.54	2.46	0	0	1.30	1.25	0	21.55	0	0.40	0.08	0	0.50	0.98
Collins	Leaf	.....	3.35	4.75	0	0	0	0	0	0	8.10	0	0.01	0	0.03	0.02	0.06
Laurel	....do	.....	9.09	0.28	0.05	0	0.10	1.57	0	T.	11.09	0	T.	T.	0.23	T.	0.23
Hattiesburg [1]	....do	.....	4.10	3.75	0.29	0.14	0	0	0	0	8.28	0	0	0.38	0	0.15	0.53
Merrill [1]	Pascagoula	.....	12.35	3.60	4.00	0	0	0	(*)	(*)	19.95	0	(*)	1.25	0	0	1.25
Aberdeen [1]	Tombigbee	T.	0.08	6.02	1.76	0.05	0.56	1.85	1.60	T.	11.92	0.40	0.18	0.03	0.15	0.24	1.00
Agricultural College	....do	0.16	2.00	2.60	0.64	0.27	0.22	2.32	0.12	0.12	8.45	T.	0	0	T.	T.	T.
Booneville	....do	0.14	0.58	5.14	0.52	0.06	0.56	0.47	0	0	7.47	0.46	0	T.	0.38	0.82	1.66
Columbus [1]	....do	0	0.43	5.35	1.15	0.23	0.45	2.20	0.84	0	10.65	T.	0.15	0.75	T.	0	0.90
Fulton	....do	0	1.44	6.16	1.78	0.19	0.54	2.04	0	0.20	12.32	0	0.66	0.39	T.	0.22	1.27
Macon [1]	....do	0	0.60	4.20	0.72	0.23	0.70	1.02	0.07	0.16	7.70	T.	0	0	0	0.37	0.37
Okolona [1]	....do	0	0.00	4.80	3.40	0.05	0.15	0.40	0.35	0	9.15	0	1.25	0.22	0	1.15	2.62
Porterville	....do	0	0.00	3.00	2.50	1.50	0.30	0.30	0.40	0	8.00	0.35	0	0.10	0	0	0.45
Tupelo	....do	0.13	1.65	4.67	1.15	0.03	0.45	0.68	0.08	0.07	8.91	2.14	0.05	0	0.50	0	2.69
Alabama—																	
Cochrane [1]	....do	0.10	1.85	5.23	1.50	0.40	1.35	1.40	0.55	0.50	12.78	1.00	0.00	0.00	0.00	0.00	1.00
Hamilton [1]	....do	0	0.10	3.21	3.22	0.31	0.32	0.86	0.65	0.03	8.52	0.17	0.55	0	0.04	0.10	0.86
Demopolis [1]	....do	0	2.52	4.42	0.31	0.55	0.40	0.92	0	1.97	11.09	0.26	0	0	0.49	0.04	0.79
Healing Springs [1]	....do	0	0	6.10	9.87	1.45	0	1.24	0.30	0.42	19.38	0	0	0	0	T.	T.
Livingston [1]	....do	0	2.43	4.12	0.58	0.44	0.41	0.97	0	0.87	9.82	0.17	0	0	0	0	0.17
Pushmataha	....do	0.50	7.00	1.92	0.32	0	0	0	1.28	0.11	10.63	0.26	0	0	0.03	0.88	1.17
Thomasville [1]	....do	T.	4.70	5.20	3.36	0.30	0.28	0	0.60	0.20	14.64	0.48	T.	0.34	0	T.	0.82
Bermuda	Escambia	.....	8.00	2.30	2.65	0.22	T.	0.10	T.	0.56	13.83	T.	0.36	T.	T.	T.	0.36
Evergreen [1]	....do	.....	11.95	3.32	3.35	0.35	0	0	0.22	.....	19.19	0.15	0	0	0	0	0.15
Flomaton	....do	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Fort Deposit [1]	....do	0.08	2.20	4.30	1.48	0.20	0.15	0.95	0.10	0	9.38	0.08	0	0	0.10	0.06	0.24
Greenville [1]	....do	0	2.70	2.85	1.63	0.67	T.	0.42	0	0.62	8.89	1.01	0	0	0	0	1.01
Highland Home	....do	0.16	4.20	1.82	0.29	0.07	0.74	0.23	0.15	0.49	8.01	0	0	0	0	T.	T.
Troy	....do	0.20	2.26	3.80	1.77	0.43	0.70	0.29	0.10	0.79	10.14	0	0.38	0.65	0	0.52	1.55
Bridgeport [1]	Tennessee	0	0	1.05	1.95	0.87	0.62	1.22	0	0.16	5.87	0	0	0.12	0.04	0	0.16
Decatur [1]	....do	0	0.04	2.10	4.20	0.98	0.32	0.10	0.60	0.18	8.61	0.20	0	0	0	1.82	2.02
Florence [1]	....do	0	0	2.42	5.64	0.84	0.30	0.84	0.44	0.04	10.52	1.44	0	0.06	0.28	0	1.78
Guntersville [1]	....do	0	0.40	2.95	2.60	1.71	0.95	0.72	0	0.25	9.58	1.35	0	0	0.10	0	1.45
Madison	....do	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Riverton [1]	....do	0	0	2.10	4.23	0.05	0.28	0.19	0.75	T.	7.60	0.97	0.64	0	0	0.56	2.17
Scottsboro	....do	0.14	0.41	1.60	2.45	0	1.45	0.47	T.	0.59	6.97	0	0	0.04	0.32	0.27	0.63
Tuscumbia [1]	....do	0	0	2.30	5.04	0.42	0.50	0.21	1.12	0	9.49	0.65	0	0	0.70	0	1.35
Auburn	Tallapoosa	T.	1.38	3.23	3.61	1.10	0.55	0.18	0.28	T.	10.33	T.	0	0.42	T.	T.	0.42
Camp Hill	....do	0	2.15	2.70	1.10	1.63	0.60	0.11	0.55	0.95	9.79	0	0	1.20	0	0.10	1.30
Dadeville	....do	0	0.60	3.60	3.30	1.50	2.22	0.35	0	0.10	11.67	0.35	0	0.20	0	0	0.55
Milstead [1]	....do	0	0.55	4.05	1.95	1.05	0.24	0.48	0.20	T.	8.52	0.04	1.00	2.30	0	T.	3.34
Opelika [1]	....do	0	0.31	1.27	2.65	3.64	1.00	0.20	0.21	0.49	8.77	0	0.07	T.	0	0	0.07
Tallassee [1]	....do	0	0.35	3.93	2.35	0.85	0.55	1.16	0.66	0.03	9.88	0.06	0.01	5.12	0.10	0.02	5.31
Tuskegee	....do	0	1.98	3.60	2.02	1.00	0.26	0.33	T.	0.21	9.40	T.	0	0.66	T.	T.	0.66
Union Springs [1]	....do	0.08	0.60	1.01	2.10	0.20	0.06	0.60	0.90	0.13	5.60	0.25	0	0.11	0	0.15	0.51
Benton	Alabama	0.00	3.20	2.64	2.98	0.00	0.00	0.82	0.31	0.64	10.59	0.42	0.00	0.00	0.69	0.00	1.11
Citronelle [1]	....do	2.38	3.99	3.47	0	0	0.17	1.05	0.02	0.24	8.94	0.78	0	0	0	1.06	1.84
Montgomery [2]	....do	0.13	5.66	2.35	0.78	0.49	1.14	0.52	0.08	0.03	11.05	0	1.50	0	T.	0.05	1.55
Prattville	....do	T.	5.37	3.36	0.17	0.29	0.80	0.60	0.19	0.62	11.40	0	0	0.20	0.08	0.12	0.40
Selma [1]	....do	0	2.44	2.90	4.87	0.33	0.20	0.98	0	0.35	12.07	0.88	0	0.03	0.08	0.02	1.01
Birmingham [2]	Black Warrior	0.26	4.58	7.02	0.67	0.53	1.47	0.01	T.	0.08	14.36	0.81	0	0.87	1.74	0.13	3.55
Cordova	....do	T.	3.38	6.25	2.00	1.55	1.22	0.10	0	1.23	15.73	0	0	0	0.31	2.13	2.44
Greensboro [1]	....do	0	1.03	6.21	1.53	0.67	0.68	0.91	0	0.58	11.61	0.09	0	0	0	0.78	0.87
Oneonta	....do	0.18	1.90	4.53	2.67	0.75	0.98	0.08	0.05	0.35	11.31	0.32	0.05	0.03	0	1.97	2.37
St. Bernard	....do	0.26	0.58	5.51	2.78	0.36	0.63	0.69	0	0.26	10.81	T.	T.	0.03	1.27	0.01	1.31
Tuscaloosa [1]	....do	0.55	0.35	8.37	1.90	0.73	0.68	1.12	0	0.56	13.71	1.49	0	0	T.	0.73	2.22
Alaga [1]	Chattahoochee	0.05	1.07	0.53	12.70	5.62	0.82	1.92	0.13	0	22.79	0	T.	0.14	0.44	0.45	1.03
Eufaula [1]	....do	0	0.30	2.34	10.86	1.74	0.12	0.25	0.02	0.03	15.66	T.	0	0.68	T.	0	0.68
Bay Minette	Coast	*	12.20	5.10	0	0	1.70	0.23	0	1.21	20.44	1.44	0	0	0	0	1.44
Mobile [2]	....do	5.82	2.74	4.99	0.34	T.	0.09	1.91	0.03	0.22	10.32	2.10	0.06	0	0	0	2.16
Ozark [1]	....do	0	1.68	0.10	9.00	1.20	0.20	0.20	0.20	0.24	12.82	0	0	0	0.40	0	0.40
Robertsdale	....do	12.50	5.58	1.23	3.32	0.04	0	0.53	0.03	T.	10.73	0.26	1.23	0	0.11	0	1.60
Anniston [2]	Coosa	0.50	4.23	2.99	1.39	1.89	0.86	0.35	0.79	0.70	13.20	0.39	0	0.50	T.	0.13	1.02
Asheville	....do	0	2.50	2.00	2.50	3.10	0.60	T.	0.10	T.	10.80	0.80	0	0.60	T.	T.	1.40
Calera [1]	....do	0	0.94	7.00	3.50	0.50	0.75	0.37	0	T.	13.06	0.70	0.72	0	0.42	0.03	1.87
Clanton [1]	....do	0	0.93	11.23	5.65	0.76	0.44	1.40	0.46	1.43	22.30	0.12	0	0.07	0.12	0	0.61
Gadsden [1]	....do	0.08	0.20	4.88	2.90	1.88	0.90	0.48	0	0.38	11.62	0.64	0	0	0	1.20	1.84
Goodwater [1]	....do	0	0.80	8.05	3.17	1.30	0.40	0.55	0.10	0.17	14.54	0.47	0	0	0.15	0.15	0.77
Lock No. 4	....do	0.30	3.00	3.00	1.75	1.03	1.00	0.28	0.60	1.00	11.66	0	0	0	0.10	0.90	1.00
Maple Grove [1]	....do	0.16	3.45	3.25	2.09	0.99	0.57	0.01	0.05	0.40	10.81	0	0.10	T.	0	0.02	0.12
Mentone [1]	....do	T.	0	1.92	5.12	1.55	1.80	0.66	T.	0.12	11.17	0.28	0	0.25	T.	0.20	0.73
Talladega	....do	T.	4.90	3.75	1.45	2.00	0.55	0.85	0.10	0.20	13.80	1.00	0	0	0	0.05	1.05
Valley Head	....do	T.	0.35	2.50	4.00	1.10	0.90	0.35	0	0.10	9.30	0	0.65	T.	0.55	0	1.20
Wetumpka [1]	....do	0	0.42	3.95	1.15	0.95	0.65	1.16	0.14	0	8.42	0.20	0	0.10	0	0	0.30

[1] Precipitation measured at 7 a. m.
[2] Precipitation measured midnight to midnight.
Stations without reference mark measure precipitation about sunset.

* Amount included in next following measurement.

TABLE NO. 3.—*Daily precipitation, in inches and hundredths, July 5–18, 1916, inclusive*—Continued.

State and station.	Watershed.	July, 1916.															
		5	6	7	8	9	10	11	12	13	Total, 5–13.	14	15	16	17	18	Total, 14–18.
Florida—																	
(Western Division.)		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Apalachicola	Gulf of Mexico	7.10	0.08	0.00	1.60	0.22	0.00	0.00	0.00	0.31	9.31	0.00	0.96	0.14	0.00	0.02	1.12
Bonifay	do	4.40	*	16.10	3.50	0.05	0.40	T.	0.78	0.77	26.00	0.38	T.	0.19	T.	T.	0.57
De Funiak Springs [1]	do	0.20	1.53	0.09	10.84	3.98	0.10	0.15	0.03	0.02	16.94	0.26	0	0	0.54	0	0.80
Garniers (near)	do	2.00	6.01	0.04	3.67	2.37	0	0	0.23	0.23	14.55	0	0	0	0	0	0
Marianna [1]	do	0.70	2.00	0.41	2.90	2.38	0.35	0.75	0.18	0	9.67	0	0.12	0	0.22	0.11	0.45
Molina	do	*	6.50	2.50	0	0	0	0.33	0	0	9.33	0	1.80	0	0	0	1.80
Panama City	do	1.03	0	0.22	0.71	0	1.01	0	0	0.05	3.02	0	0.11	0	0	0.09	0.20
Pensacola [2]	do	2.55	0.14	0.38	3.91	T.	0	0.49	0.10	T.	6.57	0.28	0.63	0.53	0	0	1.44
Wausau [1]	do	3.60	0.52	0.73	2.00	1.00	0	0.05	0	0.09	7.99	0	0	0.09	0.05	0.30	0.44
(Northern Division.)																	
Archer [1]	do	1.16	0	0	0	0	0.23	0	0.04	0	1.43	0	0	0.57	0	0	0.57
Bristol	do	2.30	1.25	1.22	2.57	0.12	0.41	0.32	0	0	8.19	0	1.00	0.03	0.65	0.23	1.91
Carrabelle	do	1.08	0.96	T.	0.77	0	0.42	0.10	0	0.68	4.01	0	0	0.22	0	0	0.22
Cedar Keys	do	0	0	0	0	0.32	0	0	0	0	0.32	0	0	0	0	0	0
Crescent City	Atlantic	0.01	0.07	0.62	0.13	0	0	0.14	0	0	0.97	0	0.11	0	0	0	0.11
Federal Point	do	0.05	0.08	0.71	0.10	0.10	0.13	0	0	0	1.17	0	0.01	0	0	0	0.01
Fenholloway	Gulf of Mexico	0.05	0.07	0.16	0	4.85	0	0	T.	0.35	5.48	0.18	0	0	0	0.19	0.37
Gainesville [1]	Atlantic	0.18	0.14	0.23	0.85	0.02	0.22	0	0.02	0.32	1.98	0	0.03	0.29	0	0	0.32
Hilliard	do	0.11	0.73	0.40	0.16	1.06	0.02	0.40	0	0.05	2.93	0	0.83	0	0	0	0.83
Jacksonville [2]	do	0.17	0.43	0.25	0	0.47	0	1.22	0	T.	2.54	T.	0.40	0	0	0	0.40
Johnstown	Suwanee	0.17	T.	1.07	T.	0.25	T.	0	T.	0	1.49	0	0.23	0.02	0	T.	0.25
Lake City [1]	do	0.10	T.	0.06	0.02	1.13	0.64	0.35	0.12	T.	2.42	0	0	0.26	0	0	0.26
Live Oak	do	0	0	1.80	0	2.03	0	0.32	0	0	4.15						
Macclenny	do	0.10	2.00	0.40	T.	0.42	0.12	T.	0	0	3.04	0.18	T.	0	0	0.65	0.83
Madison [1]	do	1.17	0	T.	0.24	1.64	2.90	0.07	0	0	6.02	0.01	0	0	0	0	0.01
Melrose	Atlantic	T.	0.07	1.04	0	0.05	0	0.04	T.	0	1.20	0	0.35	0	0	0	0.35
Middleburg	do	0.10	0.25	0.30	0.10	0	0.18	0	0	0	0.93	0.75	0.08	0	0	0	0.83
Monticello	Gulf of Mexico	0.58	0	1.51	4.50	1.64	0	0.15	0	0	8.38	0	0	0.42	0.06	0	0.48
Mount Pleasant	do	2.32	0.80	0.55	2.75	0.66	0	0	0	0	7.08	0	0	T.	0.21	0.05	0.26
St. Augustine	Atlantic	0	0.19	0	0	0.30	0	0	0	0	0.49	0	0	0	0	0	0
Satsuma Heights	do	0	1.04	0.60	0	0.01	T.	0.17	0	0	1.82	0	0.30	0	0	0	0.30
Switzerland	do	0.20	0.76	0.16	0	0	0	0.19	0	0	1.31	0	0.88	0	0	0	0.88
Tallahassee [1]	Gulf of Mexico	0.30	1.20	1.56	0.95	2.08	0	T.	0.04	0	6.13	0	0.02	1.10	0.55	0.12	1.79
Georgia:																	
Canton [1]	Coosa		0.00	0.80	5.45	1.66	3.25	0.65	0.10	0.00	11.91	T.	0.21	0.00	0.23	1.08	1.52
Ramhurst	do		T.	0.92	1.27	1.71	0.28	1.15	0.20	0.20	5.73	0	1.35	0.40	0.23	0.13	2.11
Resaca [1]	do		0	0.85	2.90	3.60	3.05	0.81	0.75	0.10	12.06	0.02	0	0	0	0	0.02
Rome [1]	do		0.10	1.70	3.00	3.94	0.90	0.75	0.33	0.55	11.27	0	0	0	0.53	T.	0.53
Atlanta [2]	Chattahoochee		0.75	2.98	1.87	1.69	0.83	0.14	T.	0	8.26	0.02	0.06	0.01	0.11	0.05	0.25
Blakely	do		0.60	7.35	9.90	2.44	2.00	0.12	0	0	22.41	0.10	T.	0.11	0.94	0.52	1.67
Columbus [1]	do		0.30	1.58	5.04	2.60	0.55	0.28	1.98	T.	12.33	0	0	0.08	0	0.03	0.11
Dahlonega	do		0.11	0.87	2.64	3.51	1.43	0.53	0.34	0.50	9.93	0.08	0.54	1.08	1.34	0.58	3.62
Fort Gaines [1]	do		0.75	1.80	9.00	1.69	0.50	0.40	0.65	0.25	15.04	0	0	0	0.42	0	0.42
Gainesville [1]	do		0.50	0.55	2.10	2.45	1.15	0.55	0.40	0.45	8.15	0.80	0.62	0.12	0.75	1.54	3.83
Goat Rock [1]	do		0.33	1.43	5.36	0.93	0.60	0.04	0.70	0.01	9.42	0	0	0.13	0	0	0.13
Lost Mountain	do		0.77	2.65	3.21	0.56	0.35	0.20	0	0	7.74	0	0.12	0.12	0	0.08	0.32
Lumpkin	do		0.24	4.00	6.47	1.45	0.47	0.44	0	0	13.07	0	0.03	0	0.03	0.71	0.77
Newnan [1]	do		0.60	2.00	3.50	1.45	0.80	1.12	0.12	0.37	9.96	0	0	0.08	0.12	0.13	0.33
Norcross [1]	do		0.08	0.90	4.25	2.46	1.44	0.34	0.22	0	9.69	0.12	0.14	0.80	1.06	1.14	3.26
Talbotton	do		0.57	3.00	5.94	3.07	0.33	0.60	0	0	13.51	0	1.28	0.03	0.15	0.20	1.66
West Point [1]	do		0.65	2.40	3.14	3.19	1.05	0.20	0.47	0	11.10	0.01	T.	0.01	0.60	0	0.62
Albany [1]	Flint		0.24	0.52	4.55	5.10	1.10	0.63	0.10	0	12.24	0.02	0	0	0.82	2.15	2.99
Americus [1]	do		0.06	0.60	4.20	1.00	0.45	0.68	0.20	0	7.19	0.32	0	0	0	1.65	1.97
Bainbridge [1]	do		3.02	0.45	3.50	3.40	0.50	0.02	0.22	0	11.11	0	0	0.15	0	0.57	0.72
Butler [1]	do		0.50	1.25	4.00	1.53	0.70	0.45	0	0	8.43	0.19	0	0.60	0	0	0.79
Concord	do		1.08	2.60	1.55	2.45	0.19	0.72	0.03	0	8.62	0.01	0.12	0.04	0.91	0	1.08
Fair View	do		0.60	3.18	1.64	2.05	0.30	0.17	0.21	1.16	9.31	0.13	0.30	0.01	0.07	0.76	1.27
Marshallville [1]	do		0.10	1.66	3.57	0.90	0.27	0.77	T.	T.	7.27	0.27	T.	0	0	1.61	1.88
Montezuma [1]	do		0.10	0.31	4.09	0.81	0.36	1.28	0	0	6.95	T.	0	0	0	0	T.
Putnam	do		0.75	*	6.25	1.25	0.75	0	0	0	9.00	0	0.80	0	0	0.95	1.75
Woodbury [1]	do		0.45	2.52	4.18	1.65	0.84	.....	0.22	0.10	9.96	0.32	0	0	0.07	0.99	1.38
Abbeville [1]	Ocmulgee		0.51	1.42	3.00	2.75	2.73	0.30	0.16	0	10.87	0.34	0	0	0	0	0.34
Covington [1]	do		0.65	1.10	3.90	1.30	1.00	0.15	0	0	8.10	0	0.35	1.10	2.20	0.20	3.85
Eastman [1]	do		0.06	0.68	2.15	2.28	1.98	0.45	0.15	0	7.75	0	0	0.13	0	0.36	0.49
Griffin [1]	do		0.78	1.75	5.75	5.22	0.76	0.02	0.38	0	14.66	0.25	0	1.33	0.18	0.18	1.94
Hawkinsville [1]	do		0.15	0.95	2.75	2.20	0.65	0.10	0.18	0	6.98	0.05	0	0.07	0	0.63	0.75
Lumber City [1]	do		0.10	0.15	1.25	0.90	3.75	1.40	0.25	0	7.80	0	0.70	0.13	0	0	0.83
Macon [2]	do		1.93	1.50	0.48	0.79	1.02	0.33	0	0	6.05	0	0	0	T.	3.35	3.35
Monticello [1]	do		0.19	1.14	3.13	0.63	1.17	0.22	0.38	0.34	7.20	T.	0	0.03	0.25	0.09	0.37
Louisville	Ogeechee		0.60	0.47	0.95	1.10	0.11	0	0.02	0.03	3.28	0.27	0	0	1.38	0.04	1.69
Millen [1]	do		0	0.70	0.20	0.85	0.65	0.70	0	0	3.10	0	0.35	0.05	0	0	0.40
Statesboro	do		T.	0.28	0.47	1.00	0.50	0.29	T.	T.	2.54	1.00	0.44	0	0	0	1.44
Glennville [1]	Altamaha		0.13	0.62	0.29	0.51	0.55	0.15	1.24	T.	3.49	0.03	0.24	T.	0	0	0.27
Augusta [2]	Savannah		1.08	0.03	0.36	0.48	0.31	0.00	T.	0.21	2.47	0.09	0.49	0.00	0.42	0.00	1.00
Carlton [1]	do		0	1.10	0.78	1.00	1.34	0.14	0.10	0	4.46	0.26	0.07	1.65	0.32	0.16	2.46
Clayton	do		T.	1.00	3.90	5.25	2.72	1.19	0	T.	14.06	T.	0.18	2.00	0	0.23	2.41
Gillsville [1]	do		0.12	0.45	2.00	2.00	1.65	1.10	0	0.05	7.37	0	T.	2.50	0.20	0	2.70
Hartwell	do		0	0.20	1.58	0.81	0.69	0	0.37	0	3.65	0.09	1.44	0.35	1.44	0.02	3.34
Lisbon	do		0	0.53	1.03	0.93	0.47	0.03	0	0	2.99	0.24	1.25	0.07	0.02	0.49	2.07
Point Peter	do		0	1.00	1.75	0	1.75	0	0	0.12	4.62	0.14	1.00	0.57	0	0.42	2.13
Savannah [2]	do		1.90	T.	0.20	0.26	T.	0	T.	0.08	2.44	0.11	0.01	0	0	0	0.12
Toccoa [1]	do		0	0.03	1.19	2.96	1.44	0.20	0.61	0	6.43	0	0	1.13	2.05	0.55	3.73
Washington [1]	do		0.05	0.10	0.65	0.60	1.20	1.01	0.60	0.62	4.83	T.	0.05	0.67	0.12	1.35	2.19
Waynesboro [1]	do		0	0.20	0.21	0.51	0.79	0.21	0	T.	1.92	0.17	0.10	0.03	0	0	0.30
Warrenton [1]	do		0.20	0.13	0.55	0.40	1.15	0.64	0.05	0.33	3.45	0	0.68	0.45	0.24	0.62	1.99
Athens [1]	Oconee		0.05	1.28	1.11	0.49	0.76	0.02	0.21	0	3.92	0.44	0.02	0.76	0.10	0.10	1.42
Dublin [1]	do		0	2.26	1.80	0.88	1.71	0.28	0	0.09	7.02	0	0.06	0.31	0.19	0	0.56
Eatonton	do		1.48	1.43	0.92	0.75	0.86	0.26	0.64	0	6.34	0	0.15	0.75	0.24	0.88	2.02
Greensboro [1]	do		0	0.67	1.22	0.90	1.79	0.33	0.56	0.06	5.53	0.09	0	T.	0.09	0	0.18
Milledgeville [1]	do		0.20	1.60	1.81	0.60	2.18	1.50	0	0.11	8.00	0.59	0.03	0.34	T.	0.16	1.12
Alapaha [1]	Alapaha		0	0.39	1.45	2.45	4.00	0.72	0	0	9.01	0	0	0.18	0	0.01	0.19
Poulan	Suwanee		0.64	0.45	7.52	2.38	0.47	0.08	0	1.30	12.84	0	0	0	0.34	0	0.34
Quitman [1]	do		0	0.30	0.84	6.32	0.16	0.10	0	0.12	7.84	0.04	0	0.19	0	0	0.23
Valdosta [1]	do		0	0.30	1.10	2.40	1.50	0.30	0	0.50	6.10	0.20	0	0	0	0	0.20
St. George	St. Marys		0.09	0.01	0.06	0.12	T.	0.00	0.00	0.00	0.28	0	0.27	0.61	0.00	0.00	0.88
Tallapoosa [1]	Tallapoosa		0.19	3.59	3.30	1.36	0.63	0.80	0.02	0.29	10.18	0.39	0.08	0	0	0.87	1.34
Thomasville [2]	Ochlockonee		0.03	1.13	3.52	1.99	0.47	0.17	0	0.40	7.71	0	0.58	0.32	0.17	T.	1.07
Waycross [1]	Satilla		0.29	1.10	0.53	1.56	0.71	0.04	0.70	0	4.93	0.03	0.01	0.56	0	0	0.60
Brunswick	Coast		0.24	0.53	0.03	0.51	0.28	0	T.	0.04	1.63	0	0	0	0	0	0

[1] Precipitation measured at 7 a. m.
[2] Precipitation measured midnight to midnight.
Stations without reference mark measure precipitation about sunset.

* Included in following measurement.

TABLE NO. 3.—*Daily precipitation, in inches and hundredths, July 5–18, 1916, inclusive*—Continued.

State and station.	Watershed.	July, 1916.															
		5	6	7	8	9	10	11	12	13	Total, 5–13.	14	15	16	17	18	Total, 14–18.
South Carolina—		*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
Charleston [2]	Coast	0.00	0.00	0.00	.....	T.	T.	0.00	0.08	1.16	1.24	2.13	1.04	0.00	0.00	0.00	3.17
Georgetown	do	0	0	0	0.30	2.00	0	0	0	0.75	3.05	4.75	3.75	0.35	0	0	8.85
Allendale [1]	Savannah	0	T.	0.09	0	0.80	0.32	0.71	0	0	1.92	0.63	0.10	1.10	.....	.....	1.83
Anderson	do	0	0	0	1.61	1.11	0.81	0.15	0.60	0	4.28	.....	1.43	1.99	0.94	0.22	4.58
Calhoun Falls [1]	do	0	0.19	0.11	0.71	0.46	1.19	1.23	0.39	1.72	6.30	0.03	0.22	0.21	0.36	0.99	1.81
Clemson College	do	0	0	0.15	1.64	1.62	0.20	0	0.22	0	3.83	0.03	0.56	0.41	1.54	0	2.54
Edgefield [1]	do	0	0	0	0.88	0.40	0	0	0	0	1.28	0	0.45	0	0	0	0.45
Liberty	do	0	0	0.10	3.04	1.10	0.60	0.04	T.	0	4.88	0.20	0.32	0	0	0	0.52
Meriwether	do	0	0	1.18	0.31	1.22	0	0	0	0.10	2.81	0.34	0.27	T.	T.	T.	0.61
Mountain Rest	do	0	T.	0.45	4.98	4.30	3.35	0.30	0.33	0	13.71	0	0.10	3.80	0.37	0.75	5.02
Walhalla	do	0	0	0.51	2.98	1.22	3.08	0.08	0.12	0.06	7.65	0.04	0.29	1.08	0.02	0.05	1.48
Yemassee [1]	Combahee	0	0	0	0	0.30	0.45	0.22	0.08	T.	1.05	0.05	5.53	0.13	0	0	5.71
Blackville [1]	Edisto	0	0	0.10	0.08	0.20	0.40	0.08	0.30	0	1.06	0	0	0	0	0	0.00
Edisto [1]	do	0	0.13	0	0	1.69	0.66	0.07	0.08	0	2.63	0.44	1.93	0.38	0	0	2.75
St. George [1]	do	0	0	0	0	0.17	0.24	1.17	0	0.17	1.75	0.75	5.50	0.45	0	0	6.70
Aiken	do	0	0.21	0.07	0.11	0.53	0.77	0.13	0	0.37	2.19	0.09	0.11	0	0.04	0.05	0.29
Batesburg [1]	do	0	0	0.49	0	0.50	0.67	0.24	T.	T.	1.90	0.27	1.29	T.	0	0	1.56
Monetta	do	0	0	0	0.15	0.66	0.30	0.04	0	0.42	1.57	0.41	0.48	0	0	0.01	0.90
Trenton	do	0	T.	0.54	0.17	0.26	0.59	T.	T.	0.06	1.62	0	0.68	0	0	0.15	0.83
Summerville	Ashley	0	0	0	0.04	T.	0.50	0	0	0.30	0.84	5.24	1.55	0	0	0	6.79
Pinopolis	Cooper	0	0	0	0	0	0.48	0	0	1.00	1.48	8.50	0.73	0	0	0	9.23
Ferguson [1]	Santee	0	0	0	0	0	0.07	0	0.05	0	0.12	2.88	7.52	0.61	0	0	11.01
Rimini [1]	do	0	0	0	0	0.26	0.11	0	0	0	0.37	1.35	2.70	1.30	0	0	4.35
St. Matthews [1]	do	0	0	0	0	1.00	0.65	0	0.10	0	1.75	0.65	1.72	0.45	0	0	2.82
Columbia [2]	Congaree	0	0	0	0.09	1.39	0.33	0.02	0	T.	1.83	1.43	0.34	0	0	0	1.77
Chappells [1]	Saluda	0	0	0	0.05	0.57	0.45	0.38	0	0	1.45	0.08	1.60	0.30	0.27	0	2.25
Greenville [1]	do	0	0	0	0.16	1.34	1.12	0.50	0.02	0.20	3.34	0.01	1.06	3.50	0.38	0.01	4.96
Greenwood [1]	do	0	0	0.31	0.10	0.61	0.24	1.45	0	0.30	3.01	0.05	0.57	0.77	0	0.10	1.49
Little Mountain	do	0	0	0.06	0.90	0.90	0.08	0	0	0.50	2.44	1.00	2.50	0	0	0	3.50
Newberry	do	0	0	T.	0.30	0.90	0.62	0	0	0.05	1.87	0.70	3.10	0.28	0.23	0.01	4.32
Pelzer [1]	do	0	0	0	0.70	1.32	1.02	0.66	0	0	3.70	0.28	0.58	1.84	1.06	0	3.76
Saluda	do	0	0	0.02	0.17	0.50	0.42	0	0.19	0.25	1.55	0.18	0.70	0.07	0	0.03	0.98
Blairs [1]	Broad	0	0	0	0	1.09	0.48	0.13	0	0	1.70	0.25	4.25	0.96	0.37	0	5.83
Gaston Shoals [1]	do	0	0	0	T.	1.34	1.03	0.76	0.22	0	3.35	0.01	3.20	6.42	0.33	0	9.96
Landrum	do	0	0	0	2.05	2.25	1.38	0.21	0.16	0	6.05	0.28	3.10	2.26	1.79	0.07	7.50
Santuck	do	0	0	0	0.37	1.06	0.58	0	0	0.05	2.06	0.60	3.16	0.16	0.26	0.22	4.40
Spartanburg [1]	do	0	0	0	T.	1.08	1.12	0.17	0	0.90	3.27	T.	4.00	4.50	0.50	0	9.00
White Oak	do	0	0	0	0.05	1.97	0.17	T.	0	0.22	2.41	0.90	6.02	0	0.09	0	7.01
Camden [1]	Wateree	0	0	0	0	0.31	0.57	0	0.04	0	0.92	1.10	3.10	0	0	0	4.20
Heath Spring	do	0	0	0	0.15	1.26	0.45	0.38	0	0	2.24	5.27	0.23	0	0	0	5.50
Catawba [1]	Catawba	0	0	0	0	1.70	1.30	0.08	0.08	0	3.16	0	6.60	0.78	0	0	7.38
Winthrop College	do	.....	.....	.....	0.12	1.60	0	0.12	0.46	0	2.30	0.34	4.00	0.12	0	0	4.46
Kingstree [1]	Black	.....	.....	.....	0	0.05	0.15	0	0.60	0	0.80	3.45	12.60	0.72	0	0	16.77
Mayesville (near)	do	.....	.....	.....	0.06	0.08	0.22	0	0	0.27	0.63	6.52	4.18	T.	0	0	10.70
Oaks	do	.....	.....	.....	0	0.13	0.30	0	0	0.35	0.78	8.95	1.00	0	0	0	9.95
Centenary	Great Pee Dee	.....	.....	.....	T.	T.	0.42	0.07	0	0.67	1.16	6.75	1.78	0.02	0	0	8.55
Cheraw [1]	do	.....	.....	.....	0	0.09	0.02	0.02	0	0	0.13	0.33	9.38	0.42	0	0	10.13
Darlington [1]	do	.....	.....	.....	0	0.14	T.	0	0	0	0.14	1.55	10.10	0.88	0	0	12.53
Florence [1]	do	.....	.....	.....	0	0.36	0.05	0	0.20	0	0.61	1.28	9.15	0.66	0	0	11.09
Society Hill [1]	do	.....	.....	.....	0	0.45	0.06	0	0.03	0	0.54	1.92	8.94	0.98	0	0	11.84
Dillon	Little Pee Dee	.....	.....	.....	0.20	0.25	0	0.68	0	0.13	1.26	7.60	0.06	T.	0	0	7.66
Conway [1]	Waccamaw	.....	.....	.....	0	0	1.03	0	0	0	1.03	2.20	2.60	T.	0	0	4.80
Effingham [1]	Lynches	.....	.....	.....	0	0.24	0.33	0	0.15	0	0.72	2.50	13.25	0.60	0	0	16.35
Kershaw	do	.....	.....	.....	0	0.26	0.50	0.63	0	0	1.39	0.21	5.73	0.26	0	0	6.20
North Carolina—																	
(Western district.)																	
Blowing Rock	Great Kanawha	.....	0.00	0.00	0.20	4.50	3.08	0.25	1.05	0.18	9.26	0.30	9.85	6.50	0.00	0.35	17.00
Jefferson	do	.....	0	0	0.26	2.30	2.68	0.19	0.31	0	5.74	0.11	7.35	4.30	0.08	T.	11.84
Transon	do	.....	0	0	0.23	3.15	4.00	0.11	T.	T.	7.49	0	10.65	7.40	0	1.05	19.10
Brewers	Pedee (upper Yadkin)	.....	0	0	0.17	2.90	1.90	0.19	0.45	0.02	5.63	0.50	6.68	3.13	0.42	0.50	11.23
Elkin [1]	do	.....	0	0	0	0.42	2.15	0.30	0	0	2.87	0.24	1.07	1.93	0.31	0.52	4.07
Mount Airy	do	.....	0	0	0	1.85	0.61	0.12	0.03	T.	2.61	0.03	2.95	0.63	0.03	1.41	5.05
North Wilkesboro	do	.....	0	0	0.10	1.90	2.03	0.06	0	0.26	4.35	0.25	9.08	2.38	0	0.25	11.96
Altapass (near)	Santee (Catawba)	.....	0	0.30	1.15	3.30	3.50	0.17	0.30	T.	8.72	0	3.90	19.32	0.55	0.03	23.80
Chimney Rock	do	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Globe (near)	do	.....	0	0	0.97	4.90	2.54	0.30	0	0	8.71	0.35	7.90	10.10	0.38	0.38	19.11
Gorge (near)	do	.....	0	0.06	1.26	4.65	1.89	0.22	0.52	0.10	8.70	0.50	10.02	10.43	0.03	0.45	21.43
Hickory	do	.....	0	0	0.30	1.32	1.47	0.30	0.04	0	3.43	0.19	9.88	3.30	0.02	0.92	14.31
Lenoir	do	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Marion	do	.....	0	0.39	1.22	2.08	3.21	0.41	0	0	7.31	0.26	7.83	3.69	1.14	0.43	13.35
Morganton	do	.....	0	0.10	0.72	1.92	0.68	0.06	0.05	0	3.53	0.05	4.67	4.79	0.22	0.28	10.01
Tryon	do	.....	0	1.45	0	5.10	2.60	0.80	0.10	0.15	10.20	2.17	3.16	7.06	0.05	0.50	12.94
Rock House	Savannah	.....	0.13	0.84	7.08	7.34	2.50	0.80	T.	0.12	18.81	0.12	0.70	5.76	0.68	0.96	8.22
Andrews	Tennessee	.....	0	0.30	1.00	0.95	0.37	0.07	0.15	0.47	3.31	0.07	0.01	1.00	0.02	0.05	1.15
Asheville [2]	do	.....	0	0.10	2.08	1.21	0.41	0.05	0.01	0.04	3.90	0.25	1.50	1.10	0.38	T.	3.83
Banners Elk	do	.....	0	0	0	2.00	2.30	T.	0.38	0	4.68	0.50	7.20	8.66	0.77	T.	17.13
Blantyre	do	.....	0	0.30	1.65	2.35	1.30	0.08	0.15	T.	5.83	0.25	2.85	13.25	0.12	0.80	17.27
Brevard	do	.....	0	0.24	1.78	2.45	1.30	0.05	0.18	0.30	6.30	†	†	14.70	T.	0.23	14.93
Bryson City [1]	do	.....	0	0	0.18	0.92	0.43	0.10	0.02	0.03	1.68	0	0	0	0.05	0.20	0.25
Cane River	do	.....	0	0.10	0.81	1.67	0.12	0.07	0.08	0	2.85	0.86	0.18	1.73	1.57	0.07	4.41
Cullowhee	do	.....	0	0.22	0.92	1.32	0.42	0.02	0.10	0.16	3.16	0.01	0.82	1.02	T.	0.18	2.03
Eagle Nest	do	.....	0	T.	1.40	0.76	0.32	T.	0	0	2.48	0.01	0.75	0.65	T.	T.	1.41
Ellijay	do	.....	0	0.06	1.05	1.68	0.85	0.16	0.75	0.02	4.57	0.03	0.30	1.68	0.01	0.83	2.85
Hendersonville	do	.....	0	0.65	1.84	2.40	1.62	0.03	0.23	0.02	6.79	0.22	2.38	9.92	0.02	0.11	12.65
Highlands	do	.....	0	0.55	4.50	7.43	3.44	0.80	0.29	0	17.01	0.05	0.53	5.77	0.63	T.	6.98
Hot Springs	do	.....	0	0	0.82	0.54	0.10	0	0	0	1.46	0	0	0.12	0.14	T.	0.26
Marshall [1]	do	.....	0	0	0.20	1.52	0.77	T.	T.	0	2.49	0	0.25	0.69	1.55	0	2.49
Murphy [1]	do	.....	0	T.	1.09	1.49	1.26	0.59	0.65	0	5.08	0.20	0.07	0.07	0.90	0.49	1.73
(Central district.)																	
Lumberton [1]	Lumber	0.00	0.00	0.00	0.00	0.05	0.25	0.00	0.02	0.00	0.32	0.83	5.00	0.10	0.00	0.00	5.93
Pinehurst	do	0	0	0	0	0	0	0	0	0	0	2.25	0.22	0	0	0	2.47
Sanatorium	do	0	0	0	0	.93	0.02	0	0	0.02	0.97	2.98	1.70	0	0	0	4.68
Southern Pines	do	0	0	0	0	0.05	0	T.	0	0	0.05	2.25	1.50	0	T.	0	3.75
Albemarle	Pedee (lower Yadkin)	0	0	0	0.18	0.18	0.51	0.15	0	0.02	1.01	0.44	4.70	0.08	0.11	0	5.33
Monroe	do	0	0	0	0.15	0.41	0.35	0.34	0	0	1.25	1.10	4.36	0	0	0	5.46
Rockingham	do	0	0	0	0	0.15	0	0	0	0	0.15	0.18	2.60	0.45	0	0	3.23
Salisbury [1]	do	0	0	0	0	0.30	0.39	1.55	0	0	2.24	0	2.18	1.08	0.10	0	3.36
Settle	do	0	0	0	0.05	2.10	0.67	0.32	0	0	3.14	0.22	3.80	0.90	0	T.	4.92

[1] Precipitation measured at 7 a. m.
[2] Precipitation measured midnight to midnight.
Stations without reference mark measure precipitation about sunset.

† Rainfall not measured until p. m. of the 16th.

TABLE NO. 3.—*Daily precipitation, in inches and hundredths, July 5–18, 1916, inclusive*—Continued.

State and station.	Watershed.	July, 1916.															
		5	6	7	8	9	10	11	12	13	Total, 5–13.	14	15	16	17	18	Total, 14–18.
North Carolina—Continued.		*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
(Central district.)																	
Statesville	Pedee (lower Yadkin).	0	0	0	0.05	1.90	1.52	0.72	0	0.12	4.24	3.52	1.33	0.43	1.62	0	7.02
Winston-Salem [1]	do.	0	0	0	0	0.19	0.23	0.47	0.42	0	0.91	0	0.81	2.63	0.31	0.66	4.41
Caroleen	Santee.	0	0	0.31	0.43	2.00	0.38	0.08	0.63	0	3.83	0.13	8.00	2.55	0	0.02	10.68
Charlotte [2]	do.	0	0	0	0.20	2.57	0.17	T.	0	0	2.94	0.53	4.61	0.01	0	T.	5.15
Kings Mountain	do.																
Lincolnton	do.	0	0	0	0.30	0.90	0.40	0.62	T.	T.	2.22	0.21	10.00	0.95	0.35	0.62	12.13
Mount Holly [1]	do.	0	0	0	0	0.58	1.42	0.52	0	0	2.52	0	2.10	1.35	0.13	0	3.58
(Eastern district.)																	
Beaufort	Coast.		0.00	0.00	0.00	0.00	0.00	0 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Edenton	do.		0	0	0	0	0	0	0	0	0	0	0	0	T.	0	T.
Hatteras [3]	do.		0.04	0	0	0	0	0.13	0	0	0.17	0	T.	0	0	T.	T.
Manteo	do.		0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0.04
Swan Quarter	do.		0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0.04
Wenona	do.		0	0	0.35	0	0.10	0.12	0	0	0.57	0	0	0	0	0	0
Belhaven	Pungo.		0	0	0	0	0	0	0	0	0	0	0	0.25	0.40	0	0.65
Bolton	Waccamaw.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eagletown	Chowan.		0	0	0	0.48	0.08	T.	0	T.	0.56	T.	0	0	0	0	T.
Elizabeth City	Pasquotank.		0	0	0	0	0.15	0	0	0	0.15	0	0	0	0	0	0
Elizabethtown [1]	Cape Fear.		0	0	0	0	0.25	0.95	0	0	1.20	1.10	1.25	0	0	0	2.35
Fayetteville [1]	do.		0	0	0	T.	0.50	0	0.39	0	0.89	0.03	1.20	0	0	0	1.23
Chapel Hill	do.		0	0	0	0.02	0.06	0.18	0	0.16	0.42	0.17	0.34	0.02	0.18	0	0.71
Graham [1]	do.		0	0	0	0	0.03	0.11	0.05	T.	0.19	0	0.96	0.08	0.39	0	1.43
Lillington [1]	do.		0	0	0	0	0.32	0	0.04	0	0.36	0	0.40	0	0	0	0.40
Monroe [1]	do.		0	0	0	0	0.16	0	0.05	0	0.21	0	0.51	0	0.10	0	0.61
Randleman [1]	do.		0	0	0	0	0.10	0.20	0	0	0.30	0	0.25	0.30	1.30	0	1.85
Sloan	do.		0	0	0	T.	0.17	0.04	0	1.27	1.48	0	0.05	0	T.	0	0.05
Southport	do.		0	0	0	0	0	0	0	0	0	0.68	0	0	0	0	0.68
Reidsville [1] (Roanoke River)	do.		0	0	0	0.02	0.27	0.20	0.03	0	0.52	0	0.74	0.27	0.17	0.10	1.28
Willard	do.		0	0	0	0.35	0.07	0	0	0	0.42	0.74	0	0	0	T.	0.74
Wilmington [3]	do.		0	0	0	0.20	0.08	0	0	0.13	0.41	0.55	0	0	0	T.	0.55
Greensboro [1]	do.		0	0	0	0.05	0.08	0.95	0.18	0	1.26	0	0.78	0.80	0.15	0	1.73
Enfield (near) [1]	Tar.		0	0	0	0	0.75	0.27	0	0	1.02	0	0.62	0	0	0	0.62
Greenville [1]	do.		0	0	0	0	0.02	0.13	0.01	0	0.16	0	0	0.74	0	0	0.74
Louisburg [1]	do.		0	0	0	0	0.80	0	0.46	0	1.26	0	0	0	0	0	0
Nashville [1]	do.		0	0	0	0	0.65	0.16	T.	0	0.81	T.	0	0.10	0	0	0.10
Rocky Mount [1]	do.		0	0	0	0	0.20	0.10	T.	T.	0.30	T.	0	0	0.42	0	0.42
Scotland Neck	do.		0	0	0	0.87	0	0	0	0	0.87	0.20	0	0	0	0	0.20
Tarboro [1]	do.		0	0	0	0	0.21	0	0.16	0	0.37	0	0.16	0.08	0	0	0.24
Henderson	Tar and Roanoke.		0	0	0	0.25	0	0.27	0	0	0.52	T.	0.13	T.	0	0	0.13
Weldon [1]	Roanoke.		0	0	0	T.	0.68	0.37	0	0	1.05	0	T.	0.07	0.03	0.01	0.11
Durham (near)	Neuse.		0	0	0	0.12	0	0.50	0	0	0.62	0.34	0.20	0.08	0.07	0	0.69
Goldsboro [1]	do.		0	0	0	0.01	1.09	0.02	0	0	1.12	0.01	0.52	0	0	0	0.53
Kinston	do.		0	0	0	0	0.08	0	0	0	0.08	0.22	0.18	0	0	0	0.40
Neuse [1]	do.		0	T.	0.17	0	0.76	0	0	0.38	1.31	0	0.06	0	0	0	0.06
Newbern [1]	do.		0	0	0	0	0.05	0.41	0.04	0	0.50	0.11	0.05	T.	0.04	0	0.20
Raleigh [2]	do.		0	0	T.	0.08	0.04	0.36	0	0	0.48	0.70	0.12	T.	0.02	0	0.84
Rougemont [1]	do.		0	0	T.	0	0.20	T.	0.30	0	0.50	0.40	T.	0	0	0	0.40
Smithfield [1]	do.		0	0	0	0	0.60	0	0	0	0.60	0	0.67	0	0	0	0.67
Tennessee—																	
Bluff City [1]	Tennessee.		0.00	0.09	0.00	0.82	0.74	0.00	0.00	0.24	1.80	0.00	0.00	0.78	1.65	0.02	2.45
Charleston [1]	do.		0	0.08	1.20	2.00	2.00	0.80	0.10	T.	6.18	0.03	0	0	0.90	0	0.93
Chattanooga [2]	do.		0.06	1.56	4.84	2.74	0.91	0.72	0.38	0.55	11.76	0	0	0.03	0.09	0.13	0.25
Lookout Mountain [1]	do.		0	0.42	4.08	5.34	3.98	0.96	0.08	0.38	15.24	0.29	0	0	0	0.48	0.77
Clinton [1]	do.		0	0	T.	2.35	0.60	1.15	T.	0.15	4.25	0.15	0.05	0.85	0.20	T.	1.25
Copperhill [1]	do.		0.11	1.00	1.77	0.82	0.69	0.38	0.01	0	4.78	0	0	0.78	0.32	0.83	1.93
Dandridge [1]	do.		0	0	0.04	1.20	1.30	0	0	0.32	2.86	0	0	0.74	0	0	0.74
Decatur	do.		0	0.21	1.71	2.01	1.15	1.18	0.01	0.03	6.30	0.03	0	1.30	0.01	0.02	1.36
Dunlap	do.		0.08	0.70	*	*	*	3.50	0.20	0	4.48	0.20	0	0.30	0.03	0.10	0.63
Elizabethton [1]	do.		0	0	0	0	1.02	0	0	0	1.02	0	T.	0.85	0.96	0.11	1.92
Jefferson City	do.		0	0.11	1.56	0.61	0.35	0	0	0	2.63	0.32	0	1.33	0	0.04	1.69
Johnson City [1]	do.		0	0	0	0.70	0.67	0.04	0.03	0	1.44	0.01	0.02	0.72	2.00	0.05	2.80
Kingston [1]	do.		0	0	0.12	2.06	1.40	0.38	0.52	0	4.48	0.25	0.17	2.05	0	0.02	2.49
Knoxville [2]	do.		0	T.	0.89	0.61	0.13	0.17	0	0.01	1.81	0.01	0.25	1.31	1.02	0.13	2.72
Loudon [1]	do.			0	0.18	1.58	0.88	0.15	0.07	0	2.86	0.42	0	0.28	0.29	0	0.99
McGhee [1]	do.			T.	.25	1.70	0.90	0.13	0.06	0.14	3.18	0	0.18	0.10	T.	0	0.28
Mountain City	do.			0	0.30	0.12	0	0	0	0	0.42	0	1.75	3.00	0.50	0	5.25
Newport [1]	do.			0	T.	1.30	0.30	0	0	0.50	2.10	0.20	0.30	0.04	0.08	0	0.62
Rogersville [1]	do.			0	T.	1.79	0.48	0	0	0.19	2.46	0	T.	0.57	0.30	0.08	0.95
Sevierville	do.			0	0.93	0.37	0.13	0	0.29	0.16	1.88	0.33	0	1.22	0.05	0	1.60
Tazewell [1]	do.			0	0	1.85	0.34	0.10	0	0	2.29	0	0.23	1.63	0	0.26	2.12
Palmetto	do.		1.62	3.00	1.22	0.20	0.42	0.05	1.20	7.71	0	0	0	0	0.90	0.90	
Carthage [1]	Cumberland.			0	0.08	2.24	0.50	0.19	0.71	0.95	4.67	3.44	0.04	0	0	0.02	3.50
Cross Ville	do.		0.21	3.25	2.40	0.20	0.81	0.11	0.11	7.09	0.10	T.	0.92	0.01	0	1.03	
McMinnville	do.		0.60	2.60	1.32	0.95	0.82	0.11	0.76	7.16	0	0	0	0	0.33	0.33	
Nashville [2]	do.		1.62	3.00	1.22	0.20	0.42	0.05	1.20	7.71	0	0	0	0	0.90	0.90	

[1] Precipitation measured at 7 a. m.
[2] Precipitation measured midnight to midnight.
Stations without reference mark measure precipitation about sunset.

* Included in following measurement.

TABLE 4.—*Daily gage heights on principal rivers of the East Gulf and South Atlantic States, in flood during July, 1916.*

Stations.	Rivers.	Flood stage.	July, 1916. 5	6	7	8	9	10	11	12	13	14	15	16	17	18
		Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Merrill, Miss.	Pascagoula.	20	5.2	13.7	19.7	26.0	a 26.6	25.3	23.9	22.9	22.0	21.4	21.0	20.7	20.2	19.7
Aberdeen, Miss.	Tombigbee.	33	2.8	2.8	12.2	27.0	33.6	36.7	b 36.4	36.2	35.5	34.3	33.3	32.1	30.6	29.5
Columbus, Miss.	do.	33	−0.5	−0.5	7.5	17.0	22.7	24.8	c 27.2	31.0	31.3	30.0	29.0	28.0	26.5	24.8
Cochrane, Ala.	do.	41	4.0	4.2	14.0	25.5	30.0	32.0	33.8	35.7	37.0	39.2	40.0	40.0	39.3	38.5
Demopolis, Ala.	do.	35	9.4	10.2	23.5	43.1	49.5	51.5	53.5	56.3	62.3	65.5	66.2	66.1	65.8	65.4
Tuscaloosa, Ala.	Black Warrior.	43	8.1	8.7	40.4	d 65.5	66.1	64.8	63.8	61.3	58.3	54.8	51.0	46.3	41.4	42.3
Rome, Ga.	Coosa.	30	6.4	6.4	6.6	12.0	26.6	32.4	33.9	e 34.1	31.8	27.5	26.0	23.4	20.6	15.8
Gadsden, Ala.	do.	22	3.1	2.8	7.4	14.4	22.7	26.4	27.8	28.6	29.8	30.7	f 31.4	31.2	30.4	28.8
Wetumpka, Ala.	do.	45	4.3	4.2	28.0	g 51.4	49.2	49.4	51.0	51.0	50.4	49.0	47.0	46.0	45.6	44.4
Millstead, Ala.	Tallapoosa.	40	3.6	2.8	27.0	36.2	39.8	39.4	37.6	34.2	26.2	19.7	14.6	20.2	16.2	10.4
Selma, Ala.	Alabama.	35	2.9	3.4	10.4	32.3	43.9	49.9	52.0	52.9	53.4	53.9	53.9	53.4	52.9	52.0
Bainbridge, Ga.	Flint.	25	4.0	4.3	4.3	4.6	15.1	24.2	27.9	28.7	28.7	28.2	27.5	27.6	28.1	28.2
Alaga, Ala.	Chattahoochee.	20	3.3	3.6	3.8	32.8	h 43.7	42.9	42.0	41.2	40.7	39.6	37.7	34.5	29.5	20.4
Catawba, S. C.	Catawba.	11	4.3	4.1	3.9	3.4	4.5	7.0	12.0	15.6	9.0	6.0	10.8	26.0	*i 35.0	20.0
Mount Holly, S. C.	do.	15	3.8	3.0	2.9	2.6	3.6	4.8	9.4	9.3	5.4	3.0	6.0	*23.5	j 45.0	21.0
Camden, S. C.	Wateree.	24	16.2	10.4	8.4	7.2	6.8	14.0	21.6	27.3	27.3	21.6	28.9	26.6	27.6	k 40.6
Chappels, S. C.	Saluda.	14	5.0	5.0	4.4	4.3	3.0	4.0	10.1	13.0	14.5	14.2	8.4	12.5	15.4	17.4
Blairs, S. C.	Broad.	14	5.7	5.6	5.4	5.4	6.1	7.8	11.5	12.4	8.0	7.2	14.2	l 29.0	35.5	28.7
Columbia, S. C.	Congaree.	15	4.0	1.9	1.9	1.7	1.1	1.8	6.7	10.0	7.1	5.4	9.5	20.5	m 30.9	29.7
Rimini, S. C.	Santee.	12	9.2	11.5	11.4	10.6	9.7	8.1	9.6	12.4	12.9	13.3	13.5	14.2	14.9	18.7
Cheraw, S. C.	Great Pee Dee.	27	5.2	11.3	7.8	6.2	5.0	4.4	4.0	17.2	17.5	11.1	18.3	33.0	35.1	33.7
Effingham, S. C.	Lynches.	14	4.8	4.3	5.3	5.8	5.0	4.4	3.0	2.6	2.3	•2.5	17.0	17.8	18.5	17.1
Kingtree, S. C.	Black.	12	1.3	1.1	1.1	1.2	1.1	0.9	0.9	1.4	1.2	1.9	12.4	14.3	q 15.4	14.8
Radford, Va.	New.	14	0.5	0.3	0.3	0.3	0.3	0.7	5.3	2.5	1.3	1.0	1.2	r 32.0	10.0	9.0

Stations.	Rivers.	July, 1916. 19	20	21	22	23	24	25	26	27	28	29	30	31	Above or below previous high.
		Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Merrill, Miss.	Pascagoula.	18.9	18.4	19.1	19.4	19.4	19.2	19.3	19.7	19.7	19.7	19.6	19.2	18.6	+ 0.8
Aberdeen, Miss.	Tombigbee.	27.8	26.8	25.7	23.9	21.8	19.7	16.8	13.8	10.7	7.2	4.6	3.8	4.1	− 3.2
Columbus, Miss.	do.	23.0	22.0	21.0	19.7	18.2	16.7	14.2	10.2	6.7	4.5	2.8	2.3	1.8	−10.5
Cochrane, Ala.	do.	37.8	37.0	36.3	35.8	34.9	33.9	33.3	30.8	28.2	23.9	18.4	10.3	8.3	− 7.0
Demopolis, Ala.	do.	64.9	64.8	64.6	64.2	63.6	62.6	61.2	60.9	60.3	59.0	57.6	55.8	52.4	− 6.7
Tuscaloosa, Ala.	Black Warrior.	41.0	49.8	48.0	42.9	37.6	35.0	31.4	27.8	25.0	22.1	18.8	16.0	15.0	− 2.3
Rome, Ga.	Coosa.	14.7	15.3	13.5	18.3	17.8	15.3	13.0	12.0	10.2	10.7	9.7	8.8	8.6	− 6.0
Gadsden, Ala.	do.	27.5	26.0	23.6	20.0	18.6	19.5	19.0	17.4	13.6	9.7	8.2	7.3	6.3	− 5.2
Wetumpka, Ala.	do.	44.0	44.5	43.0	41.6	39.0	35.6	33.0	31.0	29.0	26.5	21.5	16.5	14.5	−10.2
Millstead, Ala.	Tallapoosa.	7.2	19.2	20.4	17.2	17.0	14.8	12.2	10.2	14.2	12.0	11.0	9.2	8.0	− 8.4
Selma, Ala.	Alabama.	51.1	50.3	50.1	50.0	49.4	48.4	46.6	44.0	41.4	38.3	34.6	28.5	23.0	− 3.1
Bainbridge, Ga.	Flint.	27.6	26.4	25.0	23.6	22.0	20.7	20.2	20.6	21.6	23.0	24.1	24.6	24.5	− 5.9
Alaga, Ala.	Chattahoochee.	19.7	22.9	22.0	21.5	23.9	25.2	28.0	26.6	24.5	21.4	17.5	15.6	13.9	+ 3.8
Catawba, S. C.	Catawba.	12.0	8.0	6.0	8.5	15.0	12.0	15.0	10.0	7.0	6.0	5.0	4.0	4.0	+12.0
Mount Holly, S. C.	do.	10.0	4.6	4.6	3.8	4.0	4.8	4.6	4.0	4.3	3.2	3.0	3.0	2.8	+22.5
Camden, S. C.	Wateree.	38.0	30.5	26.0	27.5	29.0	28.5	30.0	29.5	26.6	24.5	22.5	20.0	19.5	+ 3.3
Chappels, S. C.	Saluda.	18.8	18.2	16.0	13.5	15.6	17.6	16.4	14.2	13.5	12.4	11.5	7.4	6.9	−15.9
Blairs, S. C.	Broad.	18.0	13.5	13.0	12.8	15.8	13.2	13.9	10.2	8.8	7.3	7.1	6.6	6.2	+ 4.5
Columbia, S. C.	Congaree.	22.4	14.6	11.9	11.6	14.8	15.7	15.5	12.9	9.6	9.7	7.5	9.0	6.5	− 4.3
Rimini, S. C.	Santee.	30.1	n ϕ35.0	ϕ 33.5	ϕ 31.0	28.8	26.1	23.9	23.0	22.8	22.6	21.8	20.5	19.1	+ 2.2
Cheraw, S. C.	Great Pee Dee.	o 36.1	35.6	37.2	26.2	27.6	30.9	30.9	32.4	30.2	25.5	21.5	19.8	20.6	− 7.9
Effingham, S. C.	Lynches.	16.5	p 18.3	17.5	16.0	15.0	14.4	13.5	13.1	14.2	13.8	14.3	16.2	16.0	− 1.3
Kingtree, S. C.	Black.	13.9	13.4	13.0	12.6	12.2	11.9	11.7	11.8	12.8	13.3	14.0	14.1	13.7	+ 1.0
Radford, Va.	New.	4.5	3.5	3.0	2.6	2.0	2.0	1.8	1.5	1.3	4.5	2.6	2.0	2.0	− 2.0

a 27.0 at 7 p. m.
b 36.8 at 12:26 p. m.
c 31.5 later in the day.
d 66.3 at about 6 p. m.
e 34.3 at 6. p. m.
f 31.5 at 3 p. m.
g 51.5 at 3 p. m.
h 44.0 at 9 a. m.
i 40.4 at 7:45 p. m., estimated.
j 45.5, estimated, during a. m.
k 43.0, estimated, during p. m.
l 35.8 at about 12 o'clock night.
m 31.5 at 11:30 a. m.
n 36.0 at 1 p. m., estimated.
o 36.4 at 2 p. m.
p 18.7 at 2:15 p. m.
q 15.5 at 12 noon.
r 32.0 at noon, estimated.

*Gage washed away; readings on subsequent dates estimated.
ϕ Estimated; gage overtopped.

MEAN LAKE LEVELS DURING AUGUST, 1916.

By UNITED STATES LAKE SURVEY.

[Dated Detroit, Mich., Sept. 5, 1916.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes. Superior.	Michigan and Huron.	Erie.	Ontario.
	Feet.	Feet.	Feet.	Feet.
Mean level during August, 1916:				
Above main sea level at New York	603.73	581.04	572.80	247.36
Above or below—				
Mean stage of July, 1916	+0.08	−0.12	−0.44	−0.57
Mean stage of August, 1915	+1.37	+0.94	+0.49	+1.93
Average stage for August, last 10 years	+1.16	+0.21	+0.20	+0.87
Highest recorded August stage	−0.20	−2.47	−1.31	−0.90
Lowest recorded August stage	+2.13	+1.19	+1.42	+3.01
Average relation of the August level to—				
July level	+0.2	0.0	−0.1	−0.3
September level	0.0	+0.2	+0.3	+0.4

SECTION V.—SEISMOLOGY.

SEISMOLOGICAL REPORTS FOR AUGUST, 1916.

W. J. HUMPHREYS, Professor in Charge.

[Dated: Weather Bureau, Washington, D. C., Oct. 3, 1916.]

TABLE 1.—*Noninstrumental earthquake reports, August, 1916.*

Day.	Approximate time, Greenwich Civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA.	° ′	° ′						
1916.	*H. m.*						*M. s.*			
Aug. 2	0 44	Covelo	39 47	123 16	3	1	0 2	Rumbling		U. S. Forest Service.
6	19 40	Hollister	36 50	121 20	5	1	15	None	Rocked buildings	J. N. Thompson.
	19 40	Lonoak	36 20	120 55	4	1		do		M. L. Griffin.
	19 40	Los Gatos	37 12	121 58	3	1	5	Faint	Recorded on duplex seismograph.	I. H. Snyder.
	19 40	Merced	37 21	120 27	4	1	5	None	Doors moved	A. L. Powell.
	19 40	Paso Robles	35 34	120 40	3	1	1	Rumbling	Houses trembled	Virginia Bartlett.
	19 40	San Francisco	37 48	122 26	2	1	2	None		U. S. Weather Bureau.
	19 40	Santa Cruz	36 57	122 02	4	1	8	do	Felt by nearly everyone	W. R. Springer.
	19 40	Soledad	36 25	121 18		1				A. H. Abbott.
	19 40	Spreckels	36 35	121 38	5	2		None		A. M. Hunt.
6	20 55	Hollister	36 50	121 20						J. N. Thompson.
	20 55	Salinas	36 40	121 28	3			None		J. H. Menke, jr.
	20 55	Spreckels	36 35	121 38	5	1		do		A. M. Hunt.
7	16 15	Salinas	36 40	121 38	3					J. H. Menke, jr.
8	10 45	Salinas	36 40	121 38	3					J. H. Menke, jr.
8	11 00	Salinas	36 40	121 38	4					J. H. Menke, jr.
8	16 50	Los Gatos	37 12	121 58	4	1	10	None	Recorded on duplex seismograph.	I. H. Snyder.
	16 50	Santa Cruz	36 57	122 02	5	1	5	do	Felt by everyone	W. R. Springer.
	16 50	Soledad	36 25	121 18		1				A. H. Abbott.
	16 50	Spreckels	36 35	121 38	4	1				A. M. Hunt.
14	7 20	Lone Pine	36 37	118 01		2		Rumbling		G. F. Marsh.
21	5 00	Yorba Linda	33 51	117 50	3	1				W. A. Walker.
21	11 00	Yorba Linda	33 51	117 50	3	1				Do.
23	14 55	Eureka	40 48	124 11	5	2	30	Rumbling	Caused some alarm	U. S. Weather Bureau.
	14 55	Rohnerville	40 33	124 11	4	3				W. D. Gray.
	14 55	Shiveley	40 25	123 56	5	1	1	None		Frank Essig.
		ILLINOIS.								
24	9 00	Anna	37 27	89 18	2	2	8	None	See Missouri	Jas. I. Hale.
		MISSOURI.								
24	9 00	New Madrid	36 35	89 32	3	1			Awakened some people	Miss Josie Smith.
		NEVADA.								
3	13 50	Elko	40 51	115 45	4	3	12	None		E. M. Steninger.
	13 50	McDermitt	41 58	117 45						F. A. Swayne.
	13 50	Rebel Creek	41 39	117 45	2	1	1	None		F. W. Whitaker.
	13 50	Winnemucca	40 58	117 43	3	1	10	do		U. S. Weather Bureau.
3	14 22	McDermitt	41 58	117 45						F. A. Swayne.
	14 22	Rebel Creek	41 39	117 45	2	1	1	None		F. W. Whitaker.
	14 22	Winnemucca	40 58	117 43	3	1	10	do		U. S. Weather Bureau.
		NORTH CAROLINA.								
26	19 35	Harmony	35 55	80 48	3	1	1	Rumbling		C. H. Smith.
	19 35	Lenoir	35 55	81 36	3	1	1	None		Mrs. E. C. Ivey.
	19 35	Lincolnton	35 27	81 18	2	3		do		J. T. McLean.
	19 35	Morganton	35 45	81 38	2	1				J. B. P. Massey.
	19 35	Newton	35 42	81 14	4	1	2	Rumbling		G. L. Cline.
	19 35	North Wilkesboro	36 08	81 13	4-5	1		Faint	Felt by nearly everyone	J. Hackett.
	19 35	Statesville	35 45	80 55	5	1			Caused some alarm	Press report.
	19 35	Taylorsville	35 53	81 12	5	1	2	Rumbling		J. L. Galtney.
		WYOMING.								
12	4 00	Rongis	42 25	107 50	3	1		Rumbling.		Press report.

TABLE 2.—*Instrumental seismological reports, August, 1916.*

Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.

[For significance of symbols see this REVIEW, January, 1916, p. 39.]

Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. J. W. Green.

Lat. 57° 03′ 00″ N.; long., 135° 30′ 06″ W. Elevation, 15.2 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants: E: V = 10, T_0 = 16.6; N: V = 10, 15.4

1916.	Character.	Phase.	H. m. s.	Sec.	Amplitude. A_E μ	Amplitude. A_M μ	Distance. Km.	Remarks.
Aug. 3	.....	P_E	1 46 56	.....	.....	.....	.....	
		S_E	1 53 14	.....	.....	.....	.....	
		S_N	1 53 17	.....	.....	.....	.....	
		M_E	1 53 42	.....	20	.....	.....	
		M_N	1 54 41	.....	.....	10	.....	Paper being changed $2^h\ 05^m$ to $2^h\ 12^m$.
		F	2 48 00	.....	.....	.....	.....	
3	.....	eL	14 31 11	.....	.....	.....	.....	
		M	14 31 48	10	10	20	.....	
		C	14 35 00	.....	.....	.....	.....	
28	.....	eP_E	6 52 30	.....	.....	.....	.....	
		eP_N	6 52 36	.....	.....	.....	.....	
		S	7 03 01	.....	.....	.....	.....	
		eL_N	7 28 22	20	.....	.....	.....	
		M_N	7 36 24	.....	.....	50	.....	
		M_E	7 37 43	.....	20	.....	.....	
		C_N	7 40 00	.....	.....	.....	.....	
		F	7 59 00	.....	.....	.....	.....	

Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. P. Ulrich.

Lat. 32° 14′ 48″ N.; long., 110° 57′ 06″ W. Elevation, 769.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants: E: V = 10, T_0 = 13.9; N: V = 10, 19.1

1916.	Character.	Phase.	H. m. s.	Sec.	Amplitude. A_E μ	Amplitude. A_M μ	Distance. Km.	Remarks.
Aug. 3	.....	P_N	20 36 34	3	.....	.....	.....	
		P_E	20 37 13	2	.....	.....	.....	
		M	20 42 30	6	5	5	.....	
		F	20 48 00	.....	.....	.....	.....	
3	.....	P_N	9 01 39	.....	.....	.....	.....	P doubtful.
		P_E	9 02 20	.....	.....	.....	.....	
		L	9 04 10	7	.....	.....	.....	
		M_N	9 04 40	6	.....	10	.....	
		M_E	9 05 10	7	10	.....	.....	
		C_N	9 07 11	6	.....	.....	.....	
		C_E	9 07 26	7	.....	.....	.....	
		F	9 13 00	.....	.....	.....	.....	
3	.....	P_E	14 25 03	4	.....	.....	.....	Began while changing paper on N–S.
		M_E	14 25 49	5	40	.....	.....	
		M_N	14 26 29	4	.....	20	.....	
		F	14 35 00	.....	.....	.....	.....	
6	.....	P_N	19 44 13	3	.....	.....	.....	
		P_E	19 44 23	3	.....	.....	.....	
		M_N	19 45 26	3	.....	5	.....	
		M_E	19 46 25	8	5	.....	.....	
		F	19 52 00	.....	.....	.....	.....	
25	.....	P_N	9 55 18	.....	.....	.....	.....	Barely perceptible.
		P_E	9 55 28	.....	.....	.....	.....	
		S	10 04 00	.....	.....	.....	.....	
		M	10 18 28	.....	5	5	.....	
		C_E	10 19 00	.....	.....	.....	.....	
		C_N	10 22 00	.....	.....	.....	.....	
28	.....	e_E	7 45 26	20	.....	.....	.....	Some short period waves earlier than this, probably microseisms.
		e_N	7 51 48	18	.....	.....	.....	
		M_N	7 54 18	18	.....	10	.....	
		M_E	7 55 46	19	10	.....	.....	
		F	8 08 00	.....	.....	.....	.....	

California. *Berkeley. University of California.*

Lat., 37° 52′ 16″ N.; long., 122° 15′ 37″ W. Elevation, 85.4 meters.

(See Bulletin of the Seismographic Stations, University of California.)

California. *Mount Hamilton. Lick Observatory.*

Lat., 37° 20′ 24″ N.; long., 121° 38′ 34″ W. Elevation, 1,281.7 meters.

(See Bulletin of the Seismographic Stations, University of California.)

California. *Point Loma. Raja Yoga Academy.* F. J. Dick.

Lat., 32° 43′ 03″ N.; long., 117° 15′ 10″ W. Elevation, 91.4 meters.

Instrument: Two-component, C. D. West seismoscope.

1916.	Character.	Phase.	H. m. s.	Sec.	Amplitude. A_E μ	Amplitude. A_M μ	Distance. Km.	Remarks.
Aug. 1	.....	.....	.....	.....	*100	*100	.....	Light tremors recorded during 24 hours preceding 15h on date given.
2	.....	.....	.....	.....	*150	*150	.....	
3	.....	.....	.....	.....	*100	*200	.....	
4	.....	.....	.....	.....	*100	*200	.....	
9	.....	.....	.....	.....	*100	*200	.....	
22	.....	.....	.....	.....	*100	*100	.....	

* Amplitude on instrument.

California. *Santa Clara. University of Santa Clara.* J. S. Ricard, S. J.

Lat., 37° 26′ 36″ N.; long., 121° 57′ 63″ W. Elevation, 27.43 meters.

(*See* Record of the Seismographic Station, University of Santa Clara.)

Colorado. *Denver. Sacred Heart College. Earthquake Station.* A. W. Forstall, S. J.

Lat., 39° 40′ 36″ N.; long., 104° 56′ 51″ W. Elevation, 1,655 meters.

Instrument: Wiechert 80 kg., astatic, horizontal pendulum.

1916.	Character.	Phase.	H. m. s.	Sec.	Amplitude. A_E μ	Amplitude. A_M μ	Distance. Km.	Remarks.
Aug. 14	.....	L_N	9 20 00	.....	.....	.....	.....	Irregular sinusoid. Almost continual during second part of night. Weaker on E-W.
		M_N	12 30 00	.....	.....	.....	.....	
		F_N	15 00 00	.....	.....	.....	.....	
16	.....	M_E	1 30 00	.....	.....	.....	.....	Irregular sinusoid on both components. Stronger on E-W.
		F_E	10 40 00	.....	.....	.....	.....	
27	.....	P	22 01 00	.....	.....	.....	.....	Phases very irregular and uncertain. Amplitude and period can not be measured.
		L_E	22 10 00	.....	.....	.....	.....	
		L_N	22 12 00	.....	.....	.....	.....	
		M	22 25 00	.....	.....	.....	.....	
		F	22 39 00	.....	.....	.....	.....	

TABLE 2.—*Instrumental seismological reports, August, 1916*—Continued.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_M	Distance.	Remarks.
District of Columbia. *Washington. U. S. Weather Bureau.* Lat., 38° 54′ 12″ N.; long., 77° 03 03′ W. Elevation, 21 meters. Instrument: Marvin (vertical pendulum), undamped. Mechanical registration. Instrumental constants.. V 110, T_0 6.4								
1916. Aug. 3	.....	P.....	*H. m. s.* 1 51 42	*Sec.*	μ	μ	*Km.* 8,550	
		S?....	2 01 30	.....	.....	.....	.....	
		L.....	2 08 42	.....	.....	.....	.....	
		L.....	2 29 00	20	.....	.....	.....	
		L.....	2 36 00 / 2 41 00	20	.....	.....	.....	
		L.....	3 31 00	.....	.....	.....	.....	
		L.....	3 36 00	.....	.....	.....	.....	
		F.....	3 40 00	.....	.....	.....	.....	
3	.....	P?....	9 17 30	.....	.....	.....	.....	Phases doubtful.
		F.....	9 25 00	.....	.....	.....	.....	
3	.....	S?.....	14 04 00	.....	.....	.....	.....	
		L?....	14 07 25	.....	.....	.....	.....	
		F.....	14 15 00	.....	.....	.....	.....	
3	.....	P.....	14 31 30	.....	.....	.....	2,640	Phases not well defined.
		S.....	14 35 46	.....	.....	.....	.....	
		L.....	14 39 20	.....	.....	.....	.....	
		F.....	15 05 00	.....	.....	.....	.....	
6	.....	P.....	19 57 40	.....	.....	.....	.....	
		L.....	20 00 40	10	.....	.....	.....	
		F.....	20 08 00	.....	.....	.....	.....	
18	.....	P.....	1 20 02	.....	.....	.....	810	Record very faint on E-W.
		S.....	1 21 30	.....	.....	.....	.....	
		F.....	1 50 00	.....	.....	.....	.....	
25	.....	P.....	9 54 30	.....	.....	.....	6,820	
		S.....	10 02 50	.....	.....	.....	.....	
		L.....	10 12 00	40	.....	.....	.....	
		F.....	10 40 00	.....	.....	.....	.....	
26	.....	P.....	11 01 15	.....	.....	.....	3,170?	Phases indistinct.
		S?.....	11 06 10	.....	.....	.....	.....	
		L.....	11 10 15	12	.....	.....	.....	
		F.....	11 20 00	.....	.....	.....	.....	
26	.....	P.....	19 37 19	.....	.....	.....	520	Earthquake of western North Carolina.
		S.....	19 38 16	.....	.....	.....	.....	
		L.....	19 38 21	.....	.....	.....	.....	
		F.....	19 45 00	.....	.....	.....	.....	
28	.....	P.....	6 57 11	.....	.....	.....	5,900	
		S.....	7 04 42	.....	.....	.....	.....	
		S_R....	7 05 30	.....	.....	.....	.....	
		S_R....	7 07 55	.....	.....	.....	.....	
		L.....	7 23 50	.....	.....	.....	.....	
		L.....	7 32 00	40	.....	.....	.....	
		L.....	7 41 00	20	.....	.....	.....	
		L.....	7 48 00	16	.....	.....	.....	
		F.....	9 00 00	.....	.....	.....	.....	
District of Columbia. *Washington. Georgetown University.* F. L. Tondorf, S. J. Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: Decayed diorite. Instruments: Wiechert 200 kg., astatic, horizontal pendulums, 80 kg., vertical. Instrumental constants: E V 165, T_0 5.4, ε 0; N 143, 5.2, 0; *Z 80, 3.0, 0*								
1916. Aug. 3	.....	e_N.....	*H. m. s.* 1 46 16	*Sec.*	μ	μ	*Km.*	Mainka instrument shows at $1^h\ 46^m\ 24^s$; S? at $1^h\ 52^m\ 56^s$.
		e_E.....	1 46 49	.....	.....	.....	.....	
		eL?...	2 03 23	.....	.....	.....	.....	
		F.....	3 12 00	.....	.....	.....	.....	
25	.....	ePN...	9 53 14	.....	.....	.....	.....	
		ePE...	9 53 20	.....	.....	.....	.....	
		iS_E....	10 03 51	.....	.....	.....	.....	
		S_N....	10 03 51	.....	.....	.....	.....	No distinct maximum.
		eL.....	10 13 24	.....	.....	.....	.....	Sheet removed by mistake at $12^h\ 15^m$; tremors still on.
		F.....	(?)					
26	.....	e.....	19 36 26	.....	.....	.....	.....	Recorded on vertical instrument.
		S.....	19 38 18	.....	.....	.....	.....	
		F.....	19 44 00	.....	.....	.....	.....	
27	.....	e.....	21 07 43	.....	.....	.....	.....	
		P?.....	21 22 22	.....	.....	.....	.....	
		F.....	22 04 00	.....	.....	.....	.....	
28	.....	e.....	6 59 38	.....	.....	.....	.....	Bosch-Omori instrument shows e at $6^h\ 58^m\ 51^s$.
		iR.....	7 04 38	.....	.....	.....	.....	
		S?.....	7 07 35	.....	.....	.....	.....	S very doubtful.
		L_E....	7 22 18	18	.....	.....	.....	
		F.....	9 04 00	.....	.....	.....	.....	

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Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_M	Distance.	Remarks.
Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Wm. W. Merrymon. Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters. Instrument: Milne seismograph of the Seismological Committee of the British Association. Instrumental constant .. T_0 18.6								
1916. Aug. 3	.....	P.....	*H. m. s.* 1 40 42	*Sec.*	μ	μ	*Km.*	
		S?.....	1 45 12	.....	.....	.....	.....	
		L.....	1 49 18	.....	.....	.....	.....	
		M.....	2 04 00	20	*2.200	.....	.....	
		C.....	2 35 00	.....	.....	.....	.....	
		F.....	4 36 00	.....	.....	.....	.....	
3	.....	eP.....	21 40 12	.....	.....	.....	.....	
		L.....	21 44 06	.....	.....	.....	.....	
		M.....	21 45 36	.....	*200	.....	.....	
		C.....	21 47 00	.....	.....	.....	.....	
		F.....	21 50 36	.....	.....	.....	.....	
6	.....	L.....	22 30 00	.....	*100	.....	.....	
		F.....	23 05 00	.....	.....	.....	.....	
8	.....	L.....	4 40 30	.....	.....	.....	.....	Secondary maxima at $4^h\ 42^m\ 12^s$; $4^h\ 54^m\ 48^s$; $5^h\ 05^m\ 06^s$; $5^h\ 08^m\ 00^s$; $5^h\ 11^m\ 00^s$; $5^h\ 14^m\ 54^s$.
		M.....	4 50 48	.....	*200	.....	.....	
		F.....	5 42 00	.....	.....	.....	.....	
17	.....	L.....	10 11 18	.....	.....	.....	.....	
		M.....	10 17 24	.....	*100	.....	.....	
		F.....	10 24 06	.....	.....	.....	.....	
18	.....	P.....	1 40 24	.....	.....	.....	.....	
		L.....	1 45 54	.....	.....	.....	.....	
		M.....	1 48 24	.....	*100	.....	.....	
		F.....	1 52 30	.....	.....	.....	.....	
19	.....	L.....	8 59 00	.....	.....	.....	.....	
		M.....	9 04 00	.....	*100	.....	.....	
		F.....	9 07 06	.....	.....	.....	.....	
21	.....	L.....	5 54 48	.....	.....	.....	.....	
		M.....	5 57 00	.....	*100	.....	.....	
		F.....	5 59 00	.....	.....	.....	.....	
23	.....	L.....	22 12 24	.....	.....	.....	.....	
		M.....	22 17 36	.....	*100	.....	.....	
		C.....	22 22 42	.....	.....	.....	.....	
25	.....	P?....	10 00 00	.....	.....	.....	.....	
		S.....	10 09 24	.....	.....	.....	.....	
			10 12 36	.....	.....	.....	.....	
			10 16 42	.....	.....	.....	.....	
		L.....	10 29 06	.....	.....	.....	.....	
		M.....	10 33 24	21	*800	.....	.....	
		C.....	10 42 30	.....	.....	.....	.....	
		F.....	13 04 00	.....	.....	.....	.....	
26	.....	eP.....	11 16 00	.....	.....	.....	.....	A series of tremors of very small amplitude.
		M.....	11 42 42	.....	*100	.....	.....	
		F.....	12 36 00	.....	.....	.....	.....	
27	.....	e.....	22 57 54	.....	.....	.....	.....	
		L.....	23 16 18	.....	.....	.....	.....	
		M.....	23 18 18	.....	*100	.....	.....	
		M.....	23 24 06	.....	*100	.....	.....	
		C.....	23 28 06	.....	.....	.....	.....	
		F.....	23 54 00	.....	.....	.....	.....	
30	.....	P.....	15 14 18	.....	.....	.....	.....	
		S.....	15 18 18	.....	.....	.....	.....	
		L.....	15 21 06	.....	.....	.....	.....	
		M.....	15 21 36	.....	*400	.....	.....	
		C.....	15 25 36	.....	.....	.....	.....	
		F.....	17 12 00	.....	.....	.....	.....	

* Trace amplitude.

Kansas. *Lawrence. University of Kansas.* Department of Physics and Astronomy. F. E. Kester.

Lat., 38° 57′ 30″ N.; long., 95° 14′ 58″ W. Elevation, 301.1 meters.

Instrument: Wiechert.

Instrumental constants.. E V 177, T_0 3.4, ε 4.0; N 205, 3.4, 3.8

(No earthquake recorded during August, 1916.)

TABLE 2.—*Instrumental seismological reports, August, 1916*—Continued.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_M	Distance.	Remarks.

Maryland. *Cheltenham. Magnetic Observatory.* U. S. Coast and Geodetic Survey. George Hartnell.

Lat., 38° 44′ 00″ N.; long., 76° 50′ 30″ W. Elevation, 71.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants.		V	T_0
	E	10	32
	N	10	27

1916.			H. m. s.	Sec.	μ	μ	Km.	
Aug. 3	.....	P_E	14 36 18	3	.....	.....	.....	
		P_N	14 36 23	3	.....	.....	.....	
		L_N	14 39 29	.....	.....	.....	.....	
		L_E	14 39 40	.....	.....	.....	.....	
		M	14 40 16	8	10	5	.....	
		F	14 48 00	.....	.....	.....	.....	
25	.....	P_E	10 02 44	.....	.....	.....	.....	
		P_N	10 02 56	.....	.....	.....	.....	
		L_E	10 13 27	.....	.....	.....	.....	
		L_N	10 13 56	.....	.....	.....	.....	
		M	10 14 50	29	10	20	.....	
		F	10 31 00	.....	.....	.....	.....	
28	.....	P_E	7 26 35	.....	.....	.....	.....	Phases very uncertain.
		P_N	7 27 05	.....	.....	.....	.....	
		L_E	7 38 50	.....	.....	.....	.....	
		L_N	7 40 20	.....	.....	.....	.....	
		M_E	7 48 45	16	10	.....	.....	
		M_N	7 50 51	16	.....	30	.....	
		F	8 05 00	.....	.....	.....	.....	

Massachusetts. *Cambridge. Harvard University Seismographic Station.* J. B. Woodworth.

Lat., 42° 22′ 36″ N.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation: Glacial sand over clay.

Instruments: Two Bosch-Omori 100 kg. horizontal pendulums (mechanical registration).

Instrumental constants.		V	T_0	e:1
	E	80	23	0
	N	50	25	4:1

(Report for August, 1916, not received.)

Missouri. *Saint Louis. St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J.

Lat., 38° 38′ 15″ N.; long., 90° 13′ 58″ W. Elevation, 160.4 meters. Foundation: 12 feet of tough clay over limestone of Mississippi system, about 300 feet thick.

Instrument: Wiechert 80 kg. astatic, horizontal pendulum.

Instrumental constants..	V	T_0	e:1
	80	7	5:1

1916.			H. m. s.	Sec.	μ	μ	Km.	
Aug. 3	.....	e_N	13 58 00	.....	.....	.....	.....	
		F	14 05 00	.....	.....	.....	.....	
3	.....	e	14 31 00	.....	.....	.....	.....	
		F	14 42 00	.....	.....	.....	.....	

New York. *Buffalo. Canisius College.* John A. Curtin, S. J.

Lat., 42° 53′ 02″ N.; long., 78° 52′ 40″ W. Elevation, 190.5 meters.

Instrument: Wiechert 80 kg. horizontal.

Instrumental constants..	V	T_0	e:1
	80	7	5:1

(Report for August, 1916, not received.)

New York. *Fordham. Fordham University.* W. C. Repetti, S. J.

Lat., 40° 51′ 47″ N.; long., 73° 53′ 08″ W. Elevation, 23.9 meters.

Instrument: Wiechert, 80 kg.

Instrumental constants.		V	T_0	e:1
	E	72	7.2	1.5:1
	N	72	7.2	3.8:1

(Report for August, 1916, not received.)

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_M	Distance.	Remarks.

New York *Ithaca. Cornell University.* Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori, 25 kg., horizontal pendulums (mechanical registration).

Instrumental constants.		V	T_0	e:1
	E	13	22	4:1
	N	14	25	4:1

(Report for August, 1916, not received.)

Panama Canal Zone. *Balboa Heights.* Isthmian Canal Commission.

Lat., 8° 57′ 39″ N.; long., 79° 33′ 29″ W. Elevation, 27.6 meters.

Instruments: Two Bosch-Omori 100 kg.

Instrumental constants..	V	T_0
	10	20

(Report for August, 1916, not received.)

Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. H. M. Pease.

Lat., 18° 09′ N.; long., 65° 27′ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants.		V	T_0
	E	10	21.4
	N	10	21.1

1916.			H. m. s.	Sec.	μ	μ	Km.	
Aug. 11	.....	P	8 18 57	.....	.....	.....	.....	Local shock, felt in Vieques. Vertical force variometer disturbed.
		F	8 19 24	.....	.....	.....	.....	
28	.....	e	7 46 43	.....	.....	.....	.....	Barely perceptible on N–S.
		M	7 48 10	23	5	5	.....	
		C	7 59 00	.....	.....	.....	.....	

Vermont. *Northfiela. U. S. Weather Bureau.* Wm. A. Shaw.

Lat., 44° 10′ N.; long., 72° 41′ W. Elevation, 256 meters.

Instruments: Two Bosch-Omori, mechanical registration.

Instrumental constants.		V	T_0
	E	10	15
	N	10	16

1916.			H. m. s.	Sec.	μ	μ	Km.	
Aug. 3	.....	P?	1 51 38	.....	.....	.....	8,835?	Record very faint.
		S?	2 01 40	.....	.....	.....	.....	
		F	2 20 00	.....	.....	.....	.....	
3	.....	P_N	9 16 50	.....	.....	.....	2,290?	Phases doubtful. No record on E–W.
		S_N	9 20 38	.....	.....	.....	.....	
3	.....	e_N	14 33 20	.....	.....	.....	.....	
		F	14 50 00	.....	.....	.....	.....	
25	.....	P_N	9 55 00	.....	.....	.....	7,445	Very faint record. Nothing on E–W.
		S_N	10 03 52	.....	.....	.....	.....	
		L_N	10 19 30	30	.....	.....	.....	
		F	10 40 00	.....	.....	.....	.....	
26	.....	S?	11 05 52	.....	.....	.....	.....	Very feeble quake.
		L	11 10 30	.....	.....	.....	.....	
		F	11 25 00	.....	.....	.....	.....	
28	.....	P	6 57 47	.....	.....	.....	4,680	
		S	7 04 12	.....	.....	.....	.....	
		SR	7 06 57	.....	.....	.....	.....	
		L	7 38 00	.....	.....	.....	.....	
		L	7 43 00	.....	.....	.....	.....	
		M	7 46 00	.....	.....	.....	.....	Maximum not well defined.
		F	8 00 00	.....	.....	.....	.....	

TABLE 2.—*Instrumental seismological reports, August, 1916*—Continued.

Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.

Lat., 45° 23′ 38″ N.; long., 75° 42′ 57″ W. Elevation, 83 meters.

Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoyer, 80 kg. vertical seismograph.

Instrumental constants: V 120, T_0 26.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_M	Distance.	Remarks.
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Aug. 2	.....	e.....	{20 53 16 / 21 00 00}	6–10	.....	.....	.....	
		F.....	21 05 00	.....	.....	.....	.....	
3	.....	*O*.....	*1 30 00*	.....	.....	.....	9,800	Time of *O* approximate.
		i.....	1 51 33	.....	.....	.....	.....	Velocity of L waves is 257 km. per minute.
		i.....	2 01 32	.....	.....	.....	.....	
		eL_E...	2 08 12	22	.....	.....	.....	
		L_E....	2 13 48	18	.....	.....	.....	
		L_E....	2 29 00	32	.....	.....	.....	
		L_E....	2 36 00	20	.....	.....	.....	
		L_E....	2 39 00	25	.....	.....	.....	
		L_E....	2 50 00	18	.....	.....	.....	
		L_E....	2 58 00	16	.....	.....	.....	
		$LR1_E$..	3 28 00	20	.....	.....	.....	
		F.....	3 45 00	.....	.....	.....	.....	
3	.....	eL_E...	9 19 40	14	.....	.....	.....	
		F.....	9 25 00	.....	.....	.....	.....	
3	.....	e_E.....	14 03 30	2–3	.....	.....	.....	
		e_E.....	14 08 00	7	.....	.....	.....	
		e_E.....	14 10 00	7	.....	.....	.....	
3	.....	e_E.....	14 35 44	7	.....	.....	.....	
		e_E.....	14 40 00	7	.....	.....	.....	
		F.....	15 08 00	.....	.....	.....	.....	
6	.....	e_E.....	{19 59 00 / 20 15 00}	4–5	.....	.....	.....	
8	.....	e.....	4 48 30	10	.....	.....	.....	
		L_E....	5 15 00	20	.....	.....	.....	
		L_E....	5 23 00	18	.....	.....	.....	
		F.....	5 35 00	.....	.....	.....	.....	
18	.....	P_N....	1 20 54	.....	.....	.....	.....	
		e.....	1 27 30	.....	.....	.....	.....	
		F.....	1 50 00	.....	.....	.....	.....	
25	.....	P.....	9 55 13	.....	.....	.....	7,500	
		S.....	10 04 08	.....	.....	.....	.....	
		L_E....	10 15 18	40	.....	.....	.....	
		L_N....	10 15 36	40	.....	.....	.....	
		L.....	10 20 00	30	.....	.....	.....	
		L.....	10 30 00	20	.....	.....	.....	
		L.....	10 51 00	16	.....	.....	.....	
		F.....	11 00 00	.....	.....	.....	.....	
		$eLR1_N$	12 21 36	22	.....	.....	.....	
		$eLR\,1_E$	12 24 00	20	.....	.....	.....	
		$LR1_E$..	12 29 00	20	.....	.....	.....	
		$LR1_N$..	12 35 00	20	.....	.....	.....	
		F.....	12 40 00	.....	.....	.....	.....	
26	.....	P.....	11 10 38	.....	.....	.....	.....	
		L.....	11 23 00	.....	.....	.....	.....	
27	.....	e_E.....	23 05 28	.....	.....	.....	.....	
		e_N.....	23 06 00	.....	.....	.....	.....	
		i_E.....	23 07 34	.....	.....	.....	.....	
		L_N....	23 37 00	24	.....	.....	.....	
		F.....	23 50 00	.....	.....	.....	.....	
28	.....	*O*.....	*6 30 00*	.....	.....	.....	12,200	Time of *O* approximate.
		iS.....	6 57 45	.....	.....	.....	.....	
		iSR1...	7 04 10	.....	.....	.....	.....	
		eL.....	7 24 18	28	.....	.....	.....	
		L.....	7 27 00	20	.....	.....	.....	
		L.....	7 40 00	20	.....	.....	.....	
		L.....	7 45 00	16	.....	.....	.....	
		L.....	7 59 00	14	.....	.....	.....	
		L.....	8 21 00	14	.....	.....	.....	
		LR1...	8 28 12	25	.....	.....	.....	
		LR1...	8 33 00	20	.....	.....	.....	
		$LR1_N$..	8 56 00	18	.....	.....	.....	
		F.....	9 30 00	.....	.....	.....	.....	
30	.....	e_E.....	15 39 30	.....	.....	.....	.....	
		L_N....	15 54 00	16	.....	.....	.....	
		L_N....	16 02 00	10	.....	.....	.....	
		F.....	16 10 00	.....	.....	.....	.....	

O= time at origin.

Canada. *Toronto. Dominion Meteorological Service.*

Lat., 43° 40′ 01″ N.; long., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.

Instrument: Milne horizontal pendulum, North. In the meridian.

Instrumental constant.. T_0 18. Pillar deviation, 1 mm. swing of boom=0.50″.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_M	Distance.	Remarks.
1916.			*H. m. s.*	*Sec.*		μ	*Km.*	
Aug. 3	.....	L?....	1 47 42	.....	.....	.....	.....	P and S lost in air currents.
		L.....	1 50 30	.....	*200	.....	.....	
3	.....	L.....	2 27 03	.....	.....	.....	.....	
		L.....	2 41 18	.....	.....	.....	.....	
		M.....	2 41 30	.....	*800	.....	.....	F in air currents.
3	.....	L?....	9 14 42	.....	.....	.....	.....	
		L?....	9 16 18	.....	*50	.....	.....	F in air currents.
3	.....	e.....	13 28 48	.....	.....	.....	.....	
		L?....	13 30 24	.....	*300	.....	.....	
3	.....	L.....	14 04 48	.....	.....	.....	.....	
		iL.....	14 10 42	.....	*200	.....	.....	F in air currents.
3	.....	L.....	22 03 18	.....	.....	.....	.....	Preceded and followed by air currents. F in air currents.
		M?....	22 08 03	.....	*300	.....	.....	
6	.....	L?....	19 50 54	.....	*200	.....	.....	F in air currents.
16	.....	L.....	7 44 24	.....	*100	.....	.....	Brief little quake.
		F.....	7 48 30	.....	.....	.....	.....	
18	.....	e.....	1 30 00	.....	.....	.....	.....	
		e.....	1 33 18	.....	*50	.....	.....	
		F.....	1 44 48	.....	.....	.....	.....	
25	.....	e.....	10 03 48	.....	.....	.....	.....	Possibly two quakes, one distant.
		M.....	10 05 30	.....	.....	.....	.....	
		L.....	10 14 42	.....	.....	.....	.....	
		L.....	10 33 48	.....	.....	.....	.....	
		L.....	10 56 06	.....	.....	.....	.....	
		F.....	11 40 00	.....	.....	.....	.....	
25	.....	L?....	12 29 18	.....	*50	.....	.....	Minute thickenings.
		F.....	12 36 30	.....	.....	.....	.....	
26	.....	L.....	11 10 06	.....	.....	.....	.....	No P or S waves recorded.
		M.....	11 10 36	.....	*200	.....	.....	
		L.....	11 24 00	.....	.....	.....	.....	
		L.....	11 34 18	.....	.....	.....	.....	
		F.....	11 38 18	.....	.....	.....	.....	
27	.....	L.....	22 59 00	.....	.....	.....	.....	
		L.....	23 04 36	.....	.....	.....	.....	
		L.....	23 38 00	.....	*200	.....	.....	
		L.....	23 42 54	.....	.....	.....	.....	F in air currents.
28	.....	eP.....	6 45 48	.....	.....	.....	.....	
		S?....	6 57 30	.....	.....	.....	.....	
		iS.....	7 05 36	.....	.....	.....	.....	
		iS.....	7 12 54	.....	.....	.....	.....	
		iS.....	7 16 54	.....	.....	.....	.....	
		e.....	7 22 54	.....	.....	.....	.....	
		L.....	7 26 54	.....	.....	.....	.....	
		L.....	7 28 30	.....	.....	.....	.....	
		M.....	7 43 54	.....	*1500	.....	.....	
		L.....	8 58 48	.....	.....	.....	.....	
		L.....	9 16 48	.....	.....	.....	.....	
		L.....	10 14 48	.....	.....	.....	.....	
		F.....	10 21 54	.....	.....	.....	.....	
30	.....	L.....	15 38 30	.....	*50	.....	.....	F in air currents.

* Trace amplitude.

TABLE 2.—*Instrumental seismological reports, August, 1916*—Contd.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Canada. *Victoria, B. C. Dominion Meteorological Service.*								
Lat., 48° 24′ N.; long., 123° 19′ W. Elevation, 67.7 meters. Subsoil: Rock.								
Instrument: Wiechert, vertical; Milne horizontal pendulum, North. In the meridian,								
Instrumental constant.. T_0 18. Pillar deviation, 1 mm., swing of boom=0.54″.								
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Aug. 3	.....	P?....	1 43 30	.....	.....	.....	2,410	
		S.....	1 47 28	.....	.....	.....	.....	
		L.....	1 53 26	.....	.....	.....	.....	
		M.....	1 56 54	.....	*1000	.....	.....	
		F?....	2 08 18	.....	.....	.....	.....	
3	.....	P?....	2 09 22	.....	.....	.....	1,740	
		S.....	2 12 22	.....	.....	.....	.....	
		L.....	2 18 22	.....	.....	.....	.....	
		M.....	2 26 52	.....	*200	.....	.....	
		F.....	3 11 22	.....	.....	.....	.....	
3	.....	P.....	3 46 29	.....	.....	.....	2,410	
		S.....	3 50 27	.....	.....	.....	.....	
		L.....	3 57 24	.....	.....	.....	.....	
		M.....	3 59 23	.....	*400	.....	.....	
		F.....	4 07 49	.....	.....	.....	.....	
3	.....	L?....	9 15 45	.....	.....	.....	.....	P?, S?, and F?.
		M.....	9 16 14	.....	.....	.....	.....	
3	.....	P?....	13 46 00	.....	.....	.....	1,730	
		S.....	13 48 59	.....	.....	.....	.....	
		L.....	13 52 57	.....	.....	.....	.....	
		M.....	13 53 56	.....	*100	.....	.....	F?.
3	.....	P?....	14 25 11	.....	.....	.....	.....	
		L?....	14 25 11	.....	.....	.....	.....	
		M.....	14 26 10	.....	*400	.....	.....	
		F.....	14 33 07	.....	.....	.....	.....	
3	.....	L?....	22 06 53	.....	*200	.....	.....	P?, S?.
		M.....	22 12 23	.....	.....	.....	.....	
		F.....	22 17 23	.....	.....	.....	.....	
6	.....	P?....	19 44 41	.....	.....	.....	.....	
		S?....	19 46 10	.....	.....	.....	.....	
		L?....	19 47 40	.....	.....	.....	.....	
		M.....	19 48 39	.....	*100	.....	.....	
		F.....	19 53 07	.....	.....	.....	.....	
16	.....	P.....	7 50 26	.....	.....	.....	.....	
		M.....	7 52 56	.....	*200	.....	.....	
		F.....	7 55 56	.....	.....	.....	.....	
18	.....	P?....	1 37 57	.....	.....	.....	1,740?	
		S?....	1 40 57	.....	.....	.....	.....	
		L.....	1 42 57	.....	.....	.....	.....	
		M.....	1 44 57	.....	*200	.....	.....	
		F.....	1 48 57	.....	.....	.....	.....	
25	.....	P?....	9 56 20	.....	.....	.....	.....	May be two quakes, one being distant.
		L?....	10 04 46	.....	.....	.....	.....	
		M.....	10 07 15	.....	*500	.....	.....	
		L.....	11 23 36	.....	.....	.....	.....	
		F.....	12 18 09	.....	.....	.....	.....	
26	.....	L.....	11 13 48	.....	*100	.....	.....	Minute thickening.
		F.....	11 18 48	.....	.....	.....	.....	
28	.....	P?....	7 02 42	.....	.....	.....	.....	Earthquake in Formosa.
		S.....	7 14 37	.....	.....	.....	.....	
		L?....	7 26 01	.....	.....	.....	.....	
		M.....	7 44 12	.....	*1500	.....	.....	
		F.....	9 26 01	.....	.....	.....	.....	

* Trace amplitude.

TABLE 3.—*Late seismological reports.* (*Instrumental.*)

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Vermont. *Northfield. U. S. Weather Bureau.* Wm. A. Shaw.								
Lat., 44° 10′ N.; long., 72° 41′ W. Elevation, 256 meters.								
Instruments: Two Bosch-Omori, mechanical registration.								
Instrumental constants..				V	T_0			
				E	10	15		
				N	10	16		
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 8	.....	e_E.....	9 52 30	.....	.....	.....	.....	Phases indistinct.
		F.....	10 15 00	.....	.....	.....	.....	
17	.....	P_N?..	10 42 20	.....	.....	.....	.....	
		F.....	11 00 00	.....	.....	.....	.....	
22	.....	e_N.....	16 51 18	.....	.....	.....	.....	Phases uncertain.
		F.....	17 00 00	.....	.....	.....	.....	
Canada. *Toronto. Dominion Meteorological Service.*								
Lat., 43° 40′ 01″ N., long., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.								
Instrument: Milne horizontal pendulum, North. In the meridian.								
Instrumental constant.. T_0 18. Pillar deviation, 1 mm; swing of boom=0.50″.								
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 8	.....	L.....	9 01 24	.....	.....	.....	.....	
		L.....	9 04 54	.....	*100	.....	.....	F lost in air currents.
22	.....	L?....	6 16 30	.....	*50	.....	.....	Very doubtful as to being seismic.
28	.....	P?....	17 50 54	.....	.....	.....	.....	P preceded by air currents.
		S.....	17 53 36	.....	.....	.....	.....	
		L.....	17 56 24	.....	.....	.....	.....	
		M.....	17 58 18	.....	.....	.....	.....	
		F.....	.....	.....	.....	.....	.....	Light off.

* Trace amplitude.

Canada. *Victoria, B. C. Dominion Meteorological Service.*

Lat., 48° 24′ N.; long., 123° 19′ W. Elevation, 67.7 meters. Subsoil: Rock.

Instrument: Wiechert, vertical; Milne horizontal pendulum, North. In the meridian.

Instrumental constant.. T_0 18. Pillar deviation, 1 mm.; swing of boom=0.54″.

1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 5	.....	P?....	4 41 17	.....	.....	.....	.....	
		S.....	?	.....	.....	.....	.....	
		L.....	4 43 45	.....	.....	.....	.....	
		M.....	4 44 44	.....	*200	.....	.....	
		F.....	4 50 41	.....	.....	.....	.....	
8	.....	P.....	9 55 32	.....	.....	.....	2,200	
		S.....	9 57 12	.....	.....	.....	.....	
		L.....	10 00 10	.....	.....	.....	.....	
		M.....	10 01 40	.....	*200	.....	.....	
		F.....	10 20 00	.....	.....	.....	.....	
15	.....	P?....	0 05 05	.....	.....	.....	.....	
		S.....	?	.....	.....	.....	.....	
		L.....	?	.....	.....	.....	.....	
		M.....	0 07 33	.....	*100	.....	.....	
		F.....	0 13 01	.....	.....	.....	.....	
22	.....	L?....	6 15 31	.....	.....	.....	.....	
		M.....	6 17 31	.....	*100	.....	.....	
		F.....	?	.....	.....	.....	.....	
23	.....	M.....	11 14 02	.....	*100	.....	.....	P?, S?, L?, and F?.
28	.....	P?....	18 10 09	.....	.....	.....	1,420	
		S?....	18 12 38	.....	.....	.....	.....	
		L.....	18 15 36	.....	.....	.....	.....	
		M.....	18 24 02	.....	*200	.....	.....	
		F?....	18 37 25	.....	.....	.....	.....	

*Trace amplitude.

SEISMOLOGICAL DISPATCHES.[1]

Rome, August 3, 1916.

The volcanoes of Mount Ætna and Stromboli are in violent eruption, accompanied by underground rumblings. So intense is the heat from the flaming lava that the sea is [boiling?] in the region of the volcanoes. (Assoc. Press.)

London, August 16, 1916.

The cities of Ancona, Pesara, and Rimini, Italy, were shaken by an earthquake early to-day, says a Stefani news agency from Rome to-day. No damage was done at Ancona, but at Pesaro and Rimini houses were wrecked, and it is feared that at Rimini there has been loss of life. (Assoc. Press.)

Hickory, N. C., August 26, 1916.

At 2:45 this afternoon a sharp earthquake was felt in Hickory, Conover, Statesville, and Newton. The shock was vigorous, but not of long duration. No damage was done. The shock seemingly was purely local in character. (Assoc. Press.)

Santiago, Chile, August 26, 1916.

A severe earthquake has rocked northern Chile, according to delayed dispatches received here to-night. The inhabitants of the seaport of Tocopilla have fled to the interior. No accurate reports of loss of life or damage are yet available. (Assoc. Press.)

THE NORTH CAROLINA EARTHQUAKE OF AUGUST 26, 1916.

By RUY H. FINCH, Assistant.

[Dated: Division of Seismological Investigations, Weather Bureau, Oct. 2, 1916.]

On August 26, 1916, about 2:35 p. m., an earthquake occurred in western North Carolina with its epicenter at, approximately, latitude 36° N., longitude 81° W., or a little to the northeast of the epicenter of the earthquake of February 21, 1916.

While the area sensibly affected was very small, 3,800 square miles, and the highest intensity reported but V, Rossi-Forel, yet the earthquake is of special interest in view of the fact that fairly good records of it were obtained on the seismographs at the Weather Bureau, Washington, D. C. and Georgetown University. Considerable alarm was experienced in a few cities, but no damage occurred. Detailed reports from some of the places affected by the quake are given in Table 1, noninstrumental earthquake reports, of this REVIEW. The time of the disturbance, as given by the majority of the best reports, was $2^h\ 35^m$ p. m., Eastern Time. The time of beginning at the epicenter as determined from the seismograph record of the Weather Bureau, Washington, D. C., by means of the P-O and S-O tables of Dr. Klotz was $2^h\ 36^m\ 08^s$ p. m. The estimated distance of the epicenter from Washington, determined from S-P tables, is in close agreement with the measured distance to the approximate epicenter, the former being 323 miles and the latter 320 miles.

[1] Reported by the organization indicated and collected by the seismological station at Georgetown University, Washington, D. C.

CORRIGENDUM.

Instrumental report, Alaska, Sitka, MONTHLY WEATHER REVIEW, 43: April, 1916:

Page 218, April 18, hours should be 4 and 5 instead of 3 and 4.

SECTION VI—BIBLIOGRAPHY.

RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological and seismological work and studies:

Åkerblom, Filip.
Über die Beziehung zwischen Luftdrucksgradient, Wind und Reibung bei stationärer, geradliniger Bewegung. Stockholm. 1916. 19 p. 22 cm. (K. Svenska vetenskapsakademien. Arkiv för matematik, astronomi och fysik, bd. 11, no. 18.)

Baden. Zentralbureau für Meteorologie und Hydrographie.
Jahres-Bericht, mit den Ergebnissen der meteorologischen Beobachtungen und der Wasserstandsaufzeichnungen, für das Jahr 1913. Karlsruhe. 1914. 131 p. 6 pl. 33 cm.

Bonacina, L. C. W.
Climatic control. 2d ed. London. 1915. 167 p. 17½ cm.

Clarke, Frank Wigglesworth.
The data of geochemistry. 3d ed. Washington. 1916. 821 p. 23 cm. (U. S. Geological survey. Bulletin 616.) [Chapter 2: The atmosphere.]

Clayton, H[enry] Helm.
World meteorology. Weather variations over the earth's surface generally connected and their relation to food supply and to business conditions very marked. (*In* Science conspectus, published by the Soc. of arts, Mass. inst. of technology, Boston. 1916. v. 6, no. 1, p. 20–28.)

Jeans, J. H.
The dynamical theory of gases. 2d ed. Cambridge. 1916. vi, 436 p. 27 cm.

Leather, J. Walter.
Soil temperatures. Calcutta & London. [1915.] p. 19–84. 24½ cm. (Memoirs of the Department of agriculture in India. Chemical series, v. 4, no. 2.)

Liverpool observatory, Bidston.
Report of the director, and meteorological results, 1915. Liverpool. 1916. 47 p. 24 cm.

Lſuboslavskiĭ, Gennadiĭ Andreevich.
Osnovaniſa ucheniſa o pogodſe. [The principles of meteorology.] 2d ed. Petrograd. 1915. vii, 412 p. illus. (incl. charts, diagrs.) 5 pl. 26 cm. [In Russian.]
Sbornik v pamſat professora Gennadiſa Andreevicha Lſuboslavskago. Petrograd. 1916. iv, 311 p. 9 pl. (incl. port.). 24½ cm. (Otdſelnyĭ ottisk 29 vypuska, Izvſestiĭ Imp. lſesnogo inst.) [Miscellaneous meteorological papers, preceded by brief biographical sketches of the author. In Russian.]

Magrini, Giovanni.
Carte annuali delle piogge nella regione veneta, per gli anni 1914 e 1915. Venezia. 1916. 50 p. 2 maps. 26 cm. (Pubbl. n. 68 dell' Ufficio idrografico del R. Magistrato alle acque.)

Mörikofer, Walter.
Klimatische Normalwerte für Basel. Basel. 1916. p. 149–155. 23½ cm. (S.-A. aus den Verhandlungen der Naturforschenden Gesellschaft in Basel. Band 27.)

Nevada. Agricultural experiment station.
Annual report of the Board of control for the fiscal year ending June 30, 1915. Reno, Nev. 1916. 56 p. 23 cm. ["Department of Meterology," by J. E. Church, jr. (incl. report of Mount Rose observatory), p. 46–56.]

Philippine Islands. Weather bureau.
Annual report for the year 1914. Part 3. Meteorological observations made at the secondary stations. Manila. 1916. 339 p. 29 cm.

Platania, F.
L'Osservatorio meteorologico del Collegio Pennisi. Inizi e Sviluppo. Acireale. 1915. 8 p. 23½ cm.

Prussia. Landesanstalt für Gewässerkunde.
Jahbruch für die Gewässerkunde Norddeutschlands. Abflussjahr 1911. Berlin. 1913. 6 Hefte u. Allgemeiner Teil. 25 cm.

Switzerland. Abteilung fur Wasserwirtschaft.
Tabellarische Zusammenstellung der Hauptergebnisse der Schweizerischen hydrometrischen Beobachtungen für das Jahr 1913. [In German and French.] Bern. 1915. 87 p. 38½ cm.

Switzerland. Meteorologische Zentral-Anstalt.
Annalen. 1914. 51. Jahrg. Zürich. [1915.] v. p. 30½ cm.

Tennessee. Department of agriculture.
Tennessee ... Facts about soil, climate, and rainfall. Nashville. [1916?] 69 p. illus. (incl. maps, diagrs.). fold. map. 23 cm.

Vercelli, Francesco.
Oscillazioni periodiche e previsione della pressione atmosferica. Milano. 1916. 31 p. 2 pl. 32½ cm. (Pubbl. del Reale osservatorio astron. di Brera in Milano. n. 53.)

Voller, A.
Das Grundwasser in Hamburg. Mit Berücksichtigung der Luftfeuchtigkeit, der Lufttemperatur, der Niederschlagsmengen und der Flusswasserstände. 21. Heft., 1912. Hamburg. 1913. 7 p. 3 pl. 34 cm. (Beiheft zum Jahrb. der Hamburg. wissenschaft. Anstalten, 30, 1912.)

Vosmaer, A.
Ozone. Its manufacture, properties and uses. New York. 1916. xii, 197 p. illus. plates. 23½ cm.

Weber, Sophus.
Undersøgelser over isens damptryk. (*In* Oversigt over det Kgl. Danske videnskabernes selskabs forhandlinger, 1915. København. 1916. p. 459–507.)

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The subjoined titles have been selected from the contents of the periodicals and serials recently received in the library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of the meteorological contents of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

Engineering news. New York. v. 76. August 31, 1916.
Hufeland, O. Long-time New York rainfall as basis for sewer design. p. 393–397; 450–454.

London, Edinburgh and Dublin philosophical magazine. London. v. 32. September, 1916.
Nichols, E. H. The diurnal variation of atmospheric electrical quantities. p. 282–294.

Meteorological society of Japan. Journal. Tokyo. 35th year. September, 1916.
Nakamura, Sawemontarō. Observation of a horizontal rainbow of three bands. p. 13–15.

Royal society. Proceedings. London. ser. A. v. 92. no. A 644.
Wilson, C. T. R. On some determinations of the sign and magnitude of electric discharges in lightning flashes. p. 555–574.

Science. New York. n. s. v. 44. September 15, 1916.

Howe, Eugene C. The determination of relative humidity. p. 396–398. [Description of a ventilated psychrometer.]

Scientific American. New York. v. 115. September 16, 1916.

Bastin, S. Leonard. Curious hygrometers and barometers. Home-made devices that tell the weather. p. 264; 269.

Scientific American supplement. New York. v. 82. September 30, 1916.

Miessner, B. F. A new explanation of sound phenomena accompanying disruptive electrical discharges in air. A new theory of thunder. p. 212–214.

Académie des sciences. Comptes rendus. Paris. Tome 163. 14 août 1916.

Esclangon, Ernest. Sur les coups de canon et les zones de silence. p. 167–169.

Observatoire météorologique du séminaire-collège Saint-Martial. Bulletin semestriel. Port-au-Prince. Juillet-décembre 1915.

Scherer, J. Le cyclone du 12 août 1915 dans la République d'Haïti. p. 154–167.

Schweizerische meteorologische Zentral-Anstalt. Annalen. Zürich. 1914.

Quervain, A[lfred] de. Die Ausbreitung des Kanonendonners aus dem Sundgau, Weihnachten 1914. Anhang no. 6. p. 14–16.

Società meteorologica italiana. Bollettino bimensuale. Torino. ser. 3. v. 34. Ottobre-novembre 1915.

Negro, Carlo. Indovinelli e curiosità nel campo della meteorologia. p. 60–61.

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Cavasino, Alfonso. La frequenza nelle repliche del grande terremoto nella Marsica-Valle del Liri del 13 gennaio 1915. p. 219–291.

Palazzo, L[uigi]. Cronistoria dei terremoti etiopici anteriori all' anno 1913. p. 293–350.

Navarro Neumans, Emm. M^a. S. Essais géophysiques. Travail produit par un tremblement de terre. p. 351–361.

SECTION VII.—WEATHER AND DATA FOR THE MONTH.

THE WEATHER OF THE MONTH.

P. C. DAY, Climatologist and Chief of Division.

[Dated: Weather Bureau, Washington, Oct. 2, 1916.]

PRESSURE.

The distribution of the mean atmospheric pressure over the United States and Canada, and the prevailing direction of the winds are graphically shown on Chart VII, while the average values for the month at the several stations, with the departures from the normal, are shown in Tables I and III.

For the month as a whole the barometric pressure averaged below normal in portions of New England and the Northern Plateau States, along the northern border, and in the Canadian Provinces; in all other sections of the country it was above the normal. The negative departures were generally small, the greatest values appearing in portions of Canada. The positive departures were also small, they being greatest in portions of the Gulf States.

The month opened with relatively high pressure in the eastern half of the country, but it was near the normal elsewhere, except in the northern Rocky Mountain region, where it was below normal. During the next several days the pressure was near the normal in most sections, except in the north-central districts where it was relatively low. From the 10th to the 14th relatively high pressure obtained in the north-central States. During the latter half of the month an occasional moderate low pressure area moved slowly across the country from the far West, each in turn being followed by moderately high pressure, but, as a whole, the pressure continued much nearer the normal than usual throughout the entire month. The pressure at the close of the month was comparatively high in the East and low in the north Pacific States, while elsewhere it was near the average.

The distribution of the HIGHS and LOWS was generally favorable for southerly winds in nearly all districts to the eastward of the Rocky Mountains, while along the Pacific coast northerly winds were of greatest frequency. Elsewhere variable winds prevailed.

TEMPERATURE.

During the early portion of the month the temperature was somewhat lower over the Lake Region and central Mississippi Valley than that during the latter part of July; but the weather continued much warmer than the average in all central and north-central parts of the country. On the other hand it was generally below the normal in the north Pacific States, and the Rocky Mountain and Plateau regions during the greater part of the first half of the month. On the 10th freezing temperature was reported in the Canadian province of Alberta, followed the next day by heavy frosts occurring in North Dakota. Frosts occurred at exposed points in Oregon and Nevada on the 18th and in portions of the Rocky Mountain States during the following few days, but warm weather prevailed in most eastern districts during this time, unusually high temperatures being reported in the Lakes Region and to the eastward. On the 23d an area of cooler weather overspread the Plains States and the upper Lake Region, at the same time that the period of almost continuous high temperatures that had prevailed in the Southwest since the latter part of June was temporarily broken. Cooler weather, with light frosts, occurred in northern Minnesota and North Dakota on the 26th and 27th, and overspread most central and eastern districts toward the end of the month.

For the month as a whole the temperature averaged above the normal from the Great Plains States eastward, except in small areas in the eastern portions of Maine, Virginia, and North Carolina, and the southern portion of the Florida Peninsula, where it was normal or slightly below. Elsewhere it was generally below the normal, except in Washington, western Oregon, and northwestern California, where it was slightly above. The most marked excesses of temperature occurred from Oklahoma and Kansas northeastward to the upper Lake Region, where the month averaged from 3 to 6 degrees warmer than the normal, while in Utah and portions of adjoining States it was from 3 to 4 degrees cooler than the average.

PRECIPITATION.

The rainfall during the early part of the month was chiefly in the form of thundershowers and unevenly distributed, even over small areas. Fairly heavy falls occurred in portions of the Gulf States, in southeastern New Mexico, and southern Michigan, while there were beneficial amounts in parts of the Ohio Valley, Lake Region, and Gulf States, but scarcely any rain fell in Idaho, Nevada, the Pacific States, western Texas, and central Kansas. During the second decade heavy rains occurred in the Southern Plains States, the central and southern Mississippi Valley, northeastern Kentucky, northwestern Georgia, and the west-central part of the Florida Peninsula. Moderate rains fell over the larger part of the principal corn-growing States, thereby relieving, to some extent at least, the drought that had continued for some time in portions of that section.

On the evening of the 18th a tropical storm reached the lower coast of Texas, causing heavy rainfall, severe gales, and high tide. The storm moved up the Rio Grande Valley, decreasing steadily in intensity until it finally dissipated. Save in its lower coast section, Texas had very little rain during this decade, about two-thirds of the State receiving none. Likewise, no rain fell in southeastern Kansas, eastern Oklahoma, and over most of California and Nevada during this period.

During the remainder of the month the rainfall was generally light, except in the Atlantic States, the Ohio, and middle and lower Mississippi Valleys, and portions of the Gulf States, where it was moderate and occasionally heavy. There was no rain of consequence in the far northwestern States and generally from the Rocky Mountains westward.

For the month as a whole precipitation was fairly heavy in the coastal portion of the South Atlantic and

Gulf States and in small areas in Missouri, Illinois, Iowa, Michigan, and West Virginia. Many other sections from the Plains States eastward had moderate amounts, yet interspersed in nearly every region were small areas with less than 2 inches of precipitation, while a large section extending from central Texas to northern Kansas had less than 1 inch during the entire month. From the Rocky Mountains westward, except in portions of northern Idaho and Montana, there was less than half an inch of precipitation, and in considerable portions of central and southern California rain was entirely absent as usual.

RELATIVE HUMIDITY.

For the month, as a whole, the relative humidity east of the Mississippi River was generally above the normal, except in Florida, the Lake Region, and the southern portion of the Middle Atlantic States, where it was below the average. Likewise the month was relatively damper than usual in the northern border States west of the Mississippi River and from the Rocky Mountain region westward, save in Wyoming and portions of Idaho, where it was drier. In the Central and Southern Plains States, the relative humidity for the month averaged considerably below the normal. Much of this area of deficient relative humidity also experienced unusually hot, dry, weather throughout the month, which was rendered more bearable because of the low humidity which obtained, and few heat prostrations were reported.

GENERAL SUMMARY.

The weather for August, 1916, was characterized by continuous hot weather in much of the interior of the country east of the Rocky Mountains during the first two decades, but the closing days of the month showed a marked contrast to this condition. The month was unusually dry in Oklahoma, Kansas, Iowa, and portions of the adjoining States, which resulted in much damage to growing crops, especially to corn, but at the same time afforded an opportunity for harvesting and thrashing the small grain crops and for haying. From the Rocky Mountains westward the weather for the month presented no unusual features, except that in the north Pacific Coast States, especially Washington, August was an unusually dry month.

SEVERE STORMS.

The following notes of severe storms have been extracted from reports by officials of the Weather Bureau:

Texas.—A tropical storm of great intensity passed inland over the lower Texas coast between Brownsville and Corpus Christi on August 18, 1916. The center of the storm appears to have entered the State a little south of Riviera—about 45 miles southwest of Corpus Christi—moved rapidly northwestward nearly parallel to the Rio Grande, and dissipated in the Pecos Valley. The storm caused the loss of 20 lives, so far as known, and an estimated property damage of $1,600,000. Much open cotton was beaten to the ground and immense damage was done to dwellings, churches, windmills, and other structures. The towns of Corpus Christi, Kingsville, and Bishop were perhaps the greatest sufferers, but frame houses were damaged and windmills blown down as far north as Montell, Uvalde County.

Utah.—A tornado occurred on the Sevier River, August 5. (See detailed account on p. 459.)

Average accumulated departures for August, 1916.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	°F.	°F.	°F.	In.	In.	In.	P. ct.		P. ct.	
New England	68.4	+1.3	− 6.3	1.87	−2.00	−1.20	4.4	−0.6	81	−1
Middle Atlantic	74.1	+1.3	+ 6.5	2.20	−2.20	−2.20	4.5	−0.6	75	−1
South Atlantic	79.1	+1.3	+ 9.2	4.25	−1.90	−7.70	5.1	−0.1	81	−1
Florida Peninsula	81.6	−0.3	− 2.1	7.97	+1.00	−7.10	5.3	+0.1	78	−1
East Gulf	80.4	+1.2	+ 6.6	3.59	−1.20	0.00	4.9	−0.3	79	−1
West Gulf	82.4	+1.3	+10.8	3.00	0.00	−3.50	4.8	+0.8	73	−2
Ohio Valley and Tennessee	76.5	+2.1	+ 2.2	3.23	−0.20	−0.30	4.9	+0.4	75	+3
Lower Lakes	72.5	+2.9	− 0.2	2.29	−0.70	−1.00	3.7	−0.9	68	−3
Upper Lakes	69.5	+3.2	+ 1.9	2.66	−0.30	+1.20	4.3	−0.4	73	−2
North Dakota	66.2	−0.5	−14.0	2.49	+0.20	+1.00	4.0	0.0	70	−6
Upper Mississippi Valley	75.6	+2.7	+ 4.1	3.25	+0.70	−1.20	4.3	+0.1	71	+1
Missouri Valley	75.8	+2.0	+ 3.8	3.48	+0.10	−5.30	4.1	0.0	69	+2
Northern slope	65.8	−1.0	− 9.7	1.33	+0.10	+0.10	3.8	−0.1	58	+6
Middle slope	77.1	+1.9	+ 4.8	1.85	−0.60	−3.40	4.0	+0.2	60	+1
Southern slope	78.5	−0.6	+15.8	4.14	+2.00	−3.10	4.0	+0.1	60	−1
Southern Plateau	75.4	−1.9	− 0.5	1.06	0.00	+1.10	3.4	−0.3	50	+8
Middle Plateau	68.9	−2.7	− 2.5	0.90	+0.20	+0.40	2.6	−0.7	40	+7
Northern Plateau	69.7	−0.7	−14.5	0.76	+0.40	+2.20	2.6	+0.3	43	0
North Pacific	62.6	+0.7	− 7.1	0.24	−0.60	−4.30	4.5	−0.1	76	+9
Middle Pacific	64.5	−0.3	+ 0.1	0.12	+0.10	+0.60	3.4	−0.2	61	−6
South Pacific	69.2	−1.3	− 0.6	0.02	0.00	+4.50	2.5	−0.3	68	+2

WEATHER CONDITIONS ON THE NORTH ATLANTIC DURING AUGUST, 1915.

The data presented are for August, 1915, and comparison and study of the same should be in connection with those appearing in the REVIEW for that month.

Chart IX (XLIV–92) shows for August, 1915, the averages of pressure, temperature, and the prevailing direction of the wind at 7 a. m., 75th meridian time (Greenwich Mean Noon), together with the locations and courses of the more severe storms of the month.

PRESSURE.

The average pressure for the month, as shown on Chart IX, was remarkable for its weak gradients, and lack of any well-developed HIGHS or LOWS. While the Azores HIGH is shown on Chart IX as near its usual position it was of less intensity and of greater extent than usual. The area usually occupied by the continental HIGH was covered by a comparatively uniform pressure of about 30 inches. The Icelandic LOW was apparently shallow, although the center was too far north to come within the limits of the chart. The mean monthly barometric readings ranged from 29.86 inches in the waters adjacent to the Scandinavian Peninsula to 30.14 inches in the vicinity of the Azores, a variation considerably less than normal. Although the range in average pressure was unusually small the variation from day to day in some localities was quite marked. North of the 50th parallel and west of the 30th meridian the pressure was considerably above the monthly average during the first two and last three days of the month; it was lower than usual from the 5th to the 8th, and about the average during the remaining 22 days. Over the northeastern part of the ocean there were marked negative pressure departures during the first and last decades of the month, while between the 30th and 50th parallels the variations from the normal were comparatively small during those

periods. The West Indian hurricane that prevailed in the Caribbean Sea and Gulf of Mexico from August 10 to 17 was responsible for low pressures in the immediate vicinity of the limited storm areas, although the monthly averages were affected but little, being but slightly below the normal in that territory.

GALES.

The northern waters were remarkably free from winds of gale force, and north of the 50th parallel they occurred on only one day, in three 5° squares. Off the coast of France gales were reported on the 1st and 2d, the remainder of the month being free, while between the 20th and 30th parallels there were none reported during the month. The West Indian hurricane in the Caribbean Sea and Gulf of Mexico caused an increase in the number of gales occurring in that territory. They were reported in different 5° squares on from one to three days, the latter number being somewhat above the normal. From August 1 to 3 a LOW (shown as Track II, Chart IX, for July, XLIV–84) was central near the Irish Channel. On August 4 this had moved about 10° eastward and was fast filling in, so that no sign of it existed on the 5th. From August 3 to 10 a low area prevailed between the 40th and 55th parallels and the 20th and 40th meridians, the movement from day to day being slow and irregular. On August 4 the barometer had fallen to 29.59 inches from 29.80 inches on the 3d, and on the 5th and 6th the lowest readings were approximately 29.35 inches, the center on these days being near latitude 48° N., longitude 37° W. Light to moderate winds prevailed during the greater part of the period, although on the 6th winds of 40 miles an hour were reported by three vessels. By August 7 the center had moved about 5° in an east-north-east direction, the barometer falling to 29.28 inches, and although the area of low pressure had decreased in extent no heavy winds were reported. On the 8th the depression had moved slightly toward the west; the pressure had changed but little since the previous day and the velocity of the wind had increased somewhat. The LOW then moved about 10° in an easterly direction, and on the 9th was central near latitude 51° N., longitude 26° W. It had increased somewhat in intensity and the isobars had assumed a more definite outline, although the force of the wind remained about the same. The depression then moved toward the north, and on the 10th was near latitude 55° N., longitude 27° W., the conditions of wind and weather having changed but little since the previous day. It then began to fill in and by the 11th had practically disappeared.

On the 10th a LOW central near the Barbados marked the beginning of the severe West Indian hurricane that prevailed until the 23d. This storm (track 1 on Chart IX) was fully discussed by Prof. H. C. Frankenfield in a special bulletin on the subject and also in the MONTHLY WEATHER REVIEW for August, 1915. The positions of this storm as shown on Chart IX of this issue were plotted from the daily synoptic charts from the 10th to the 17th, while from the 18th to the 23d they were copied from Chart III, the tracks of centers of low areas for August, 1915 (M. W. R., XLIII–86). The intense character of this hurricane, as shown by its steep barometric gradients, was specially noticeable on the 17th, when the 8 a. m. barometer reading at Houston, Tex., was 28.72 inches; at Galveston, Tex., 29.12 inches; and in the Gulf of Mexico about 150 miles east of Galveston, 29.70 inches.

From August 12 to 14 a LOW of slight intensity was central near the north coast of Ireland, accompanied by light to moderate winds. By the 15th this shallow depression had moved about 10° toward the east and covered practically the same area on the 16th. It continued in a slow and irregular eastward movement, without increasing in intensity, and on the 17th, 18th, and 19th occupied the southern part of the Scandinavian Peninsula, while by the 20th it had passed beyond the limits of the chart. On the 17th a LOW appeared in the Gulf of St. Lawrence that remained practically stationary until the 21st, when it began to fill in. This depression was also of slight intensity. On the 17th and 18th fog prevailed off the banks of Newfoundland. From the 21st to the 25th the atmospheric conditions were unusually stagnant, the pressure being somewhat above the normal, with small gradients and light wind movement. On August 26 a LOW of 29.50 inches was central near Cape Whittle, Canada; this probably moved toward the north, as it did not appear on the chart of the 27th. Nearly normal conditions prevailed during the remainder of the month, and no depressions of any consequence were reported.

TEMPERATURE.

North of the 40th parallel and east of the 30th meridian the mean monthly temperature was from 1° to 3° above the normal, while nearly the same conditions held true in the southeastern part of the ocean, although there were a few 5°-squares in this territory where the temperatures were slightly lower than usual. Between the 35th and 40th parallels and 30th and 65th meridians the departures ranged from −1° to −4°, while in the waters adjacent to the American coast the temperatures varied but little from the normal.

The temperature departures for August, 1915, at a number of Canadian and United States Weather Bureau stations on the Atlantic and Gulf coasts were as follows:

	°F.		°F.
St. Johns, Newfoundland	−1.4	Norfolk, Va.	+1.3
Sydney, C. B. I.	+1.0	Hatteras, N. C.	+1.7
Halifax, N. S.	+0.8	Charleston, S. C.	+1.7
Eastport, Me.	−1.5	Key West, Fla.	+0.7
Portland, Me.	−2.4	Pensacola, Fla.	+0.2
Nantucket, Mass.	−1.0	New Orleans, La.	+1.7
New York, N. Y.	−1.8	Galveston, Tex.	−1.3
Washington, D. C.	−0.5	Corpus Christi, Tex.	+1.7

The lowest temperature reported during the month was 46°F., occurring on the 7th, 8th, and 9th, in the 5°-square between latitudes 55–60° N. and longitudes 40–45° W.

The highest temperature in this square was 56°F., and occurred on a number of days in the last decade of the month.

The extreme monthly range of temperature was, as a rule, small, the extreme range for any 5°-square being 10 degrees.

FOG.

During the period from 1901 to 1906 for the month of August the average percentage of days with fog off the banks of Newfoundland was from 40 to 45, while in the same region for August, 1915, fog was observed on from 7 to 10 days, with a percentage of from 23 to 32. The amount in the vicinity of Nantucket Island was also somewhat below the normal; east of the 40th meridian along the northern steamer routes, the percentage was never higher than 6, while the normal varies from 5 to 10.

PRECIPITATION.

No hail or snow was reported during the month.

Maximum wind velocities during August, 1916.

[Velocities below 50 mi./hour (22.4 m./sec.) are not included.]

Stations.	Date.	Velocity.	Direction.	Stations.	Date.	Velocity.	Direction.
		Mis./hr.				*Mis./hr.*	
Corpus Christi, Tex.	18	90	e.	Norfolk, Va.	23	53	nw.
Del Rio, Tex.	19	60	se.	Pensacola, Fla.	8	52	sw.
El Paso, Tex.	12	57	se.	Point Reyes Light, Cal.	4	61	nw.
Evansville, Ind.	26	77	sw.	Do.	17	67	nw.
Jacksonville, Fla.	11	52	s.	Do.	18	60	nw.
Louisville, Ky.	26	54	nw.	San Antonio, Tex.	19	56	se.
Mobile, Ala.	6	63	ne.	Sand Key, Fla.	1	50	se.
Mount Tamalpais, Cal.	3	64	nw.	San Juan, P. R.	22	92	ne.
Do.	13	55	w.	Do.	29	62	ne.
Do.	16	50	nw.	Sioux City, Iowa.	6	70	sw.
Do.	17	66	nw.	Do.	9	60	w.
Do.	24	61	nw.	Syracuse, N. Y.	22	56	sw.
Do.	31	57	nw.	Washington, D. C.	27	52	nw.

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by section, August, 1916.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	79.8	+0.2	Flomaton	104	17	3 stations	51	25	3.64	−1.04	Spring Hill	10.57	Gadsden	0.85
Arizona	77.1	−1.9	2 stations	113	7†	Fort Valley	36	21	2.76	+0.21	Paradise	8.84	2 stations	0.00
Arkansas	81.8	+2.8	2 stations	107	13†	Dutton	46	24	2.63	−1.05	Hot Springs	5.91	Fort Smith	0.23
California	73.2	+0.4	Greenland Ranch	121	2	Cohuila	20	18	0.20	+0.12	Cuyamaca	2.09	47 stations	0.00
Colorado	63.4	−1.4	Two-Buttes	105	7	Fraser	27	21†	3.06	+1.08	Trout Lake	7.39	Fort Collins	0.71
Florida	81.5	+0.1	Middleburg	102	17	Orange City	61	20	6.09	−1.47	Griffin	12.57	Cedar Keys	0.85
Georgia	80.1	+0.8	Quitman	103	17	2 stations	53	25	3.09	−2.35	St. George	11.75	Americus	0.32
Hawaii (July)	73.2	.....	Mahukona, Hawaii	94	23	Volcano Observatory, Hawaii.	51	20	5.45	.....	Hakalau (Mauka), Hawaii.	23.47	2 stations	0.00
Idaho	63.9	−1.0	Indian Cove	106	7	Elk Creek	10	18	0.77	+0.16	Sunset Lookout	3.48	Richfield	0.00
Illinois	77.0	+3.2	2 stations	101	4†	Joliet	40	28	4.15	+0.98	Mascoutah	11.45	Henry	0.68
Indiana	76.0	+2.7	Connersville	105	3†	Valparaiso	42	28	3.14	−0.20	Salem	6.61	South Bend	0.82
Iowa	74.0	+2.2	Webster City	106	4	Mattock	35	27	2.58	−1.10	Thurman	6.23	Delaware	0.49
Kansas	79.6	+2.6	Toronto	109	14	4 stations	40	28	2.01	−1.08	Fredonia	5.90	Healy	0.20
Kentucky	77.0	+1.3	Eardington	101	4†	Taylorsville	47	29	4.25	+0.90	Loretto	8.19	Russellville	0.78
Louisiana	82.0	+0.3	2 stations	105	2†	Kelly (near)	54	25	4.49	−0.59	Lakeside	10.29	Lonansport	0.25
Maryland-Delaware	74.2	+0.8	Cumberland, Md	101	22	Oakland, Md	38	14	2.18	−2.51	Oakland, Md	5.19	Milford, Del	0.50
Michigan	70.0	+3.5	Morenci	106	20	Humboldt	28	30	2.50	−0.26	Victoria	5.59	Grand Marais	0.85
Minnesota	68.4	+1.7	7 stations	98	2†	Warren	28	28	3.71	−0.01	Winnibigoshish Dam	8.89	Farmington	0.99
Mississippi	80.5	−0.3	Columbia	101	18	Charleston	50	25	3.64	−0.85	Biloxi	10.45	Aberdeen	0.25
Missouri	79.2	+2.9	Steffenville	107	4	Eldon	41	28	4.05	+0.79	Louisiana	14.86	Clinton	0.30
Montana	63.2	−0.7	Busby	104	1	Bowen	17	19	1.23	+0.11	Glentana	6.29	Poplar	0.06
Nebraska	73.2	+0.4	Beaver City	109	3†	Gordon	34	22	3.51	+0.68	Aurora	7.34	Fort Robinson	0.55
Nevada	67.7	−2.8	Pahrump	112	1	San Jacinto	21	19	0.25	−0.21	Floche	1.92	8 stations	0.00
New England	69.0	+1.7	Cornwall, Vt	104	21	Cavendish	30	29	2.75	−1.10	North Bridgton, Me	7.83	Block Island, R.I	0.57
New Jersey	73.2	+1.4	3 stations	100	22	2 stations	40	29	1.34	−3.56	Lakewood	4.15	Newark	0.27
New Mexico	69.6	−1.1	Clovis	102	14	2 stations	32	7†	3.80	+0.90	Lakewood (near)	14.56	Aztec	0.02
New York	69.9	+2.8	Wedgwood	103	22	Bolivar	32	29	2.24	−1.47	Liberty	5.30	New York City	0.59
North Carolina	76.3	+0.6	Wenona	100	12	Banners Elk	49	31	4.74	−1.30	Swan Quarter	9.76	Graham	2.25
North Dakota	65.9	+0.4	2 stations	99	3†	Mellville	26	26	2.78	+0.46	Willow City	5.38	Manfred	0.67
Ohio	74.4	+2.9	Norwalk	104	21	5 stations	39	29	3.11	−0.19	Hillsboro	8.63	Lake View	0.81
Oklahoma	83.4	+2.7	2 stations	111	3†	2 stations	45	24†	1.16	−1.89	Harney	5.85	2 stations	0.00
Oregon	65.5	+0.2	Medford (2)	106	25†	Yonna	19	18	0.50	−0.16	Government Camp	2.45	Florence (2)	0.00
Pennsylvania	71.9	+2.2	Clearfield	103	21	West Bingham	32	2†	2.57	−1.45	Punxsutawney	7.08	Kennett Square	0.21
Porto Rico	79.4	+0.2	2 stations	96	1†	Carite Dam	60	29	10.45	+2.50	Rio Grande (El Verde).	22.99	Potala (Hacienda)	4.63
South Carolina	79.6	+0.8	2 stations	100	16†	Mountain Rest	58	25	3.27	−2.99	Pinopolis	10.91	Maysville (near)	1.15
South Dakota	69.4	+0.1	2 stations	102	2†	Stephan	31	23	3.29	+0.68	Clark	9.62	Pine Ridge	1.01
Tennessee	77.6	+1.3	Arlington	102	18	Mountain City	43	25	4.88	+0.97	Tazewell	12.45	Clarksville	1.23
Texas	82.2	−0.3	Bonham	108	13	Big Spring	47	25	2.84	+0.42	Bay City	11.34	Midland	0.05
Utah	67.7	−2.7	St. George	105	23	Black Rock	29	25	1.16	−0.02	Castle Dale	3.05	2 stations	0.00
Virginia	74.3	−0.4	Diamond Springs	98	5	2 stations	40	14†	3.33	−0.32	Wytheville	9.53	Doswell	1.10
Washington	66.0	+0.5	Wahluke	112	28	2 stations	27	19	0.40	−0.46	Peola	3.02	4 stations	0.00
West Virginia	72.9	+1.4	Wheeling	104	21	Brandywine	40	14†	4.76	+0.78	Powelton	15.35	Moorefield	1.46
Wisconsin	69.8	+3.2	Prairie du Chien	104	20	Florence (3)	29	27	3.08	−0.42	Park Falls	6.77	Lancaster	0.53
Wyoming	60.9	−0.8	Thermopolis	103	1	Norris Geyser Basin	19	10	1.26	+0.13	Archer	4.35	2 stations	T.

† Other dates also.

DESCRIPTION OF TABLES AND CHARTS.

Table I gives the data ordinarily needed for climatological studies for about 158 Weather Bureau stations making simultaneous observations at 8 a. m. and 8 p. m., daily, 75th Meridian Time, and for about 41 others making only one observation. The altitudes of the instruments above ground are also given.

Table II gives a record of precipitation, the intensity of which at some period of the storm's continuance equaled or exceeded the following rates:

Duration (minutes)	5	10	15	20	25	30	35	40	45	50	60
Rates per hour (inches)	3.00	1.80	1.40	1.20	1.08	1.00	0.94	0.90	0.87	0.84	0.80

It is impracticable to make this table sufficiently wide to accommodate on one line the record of accumulated falls that continue at an excessive rate for several hours. In this case *the record is broken at the end of each 50 minutes*, the accumulated amounts being recorded on successive lines until the successive rate ends.

In cases where no storm of sufficient intensity to entitle it to a place in the full table has occurred the greatest precipitation of any single storm has been given, also the greatest hourly fall during that storm.

The tipping-bucket mechanism is *dismounted* and removed when there is danger of snow or water freezing in the same. Table II records this condition by entering an asterisk (*).

Table III gives, for about 30 stations of the Canadian Meteorological Service, the means of pressure and temperature, total precipitation and depth of snowfall, and the respective departures from normal values except in the case of snowfall.

Chart I.—Hydrographs for several of the principal rivers of the United States.

Chart II.—Tracks of centers of high areas; and

Chart III.—Tracks of centers of low areas. The roman numerals show the chronological order of the centers. The figures within the circles show the days of the month; the letters *a* and *p* indicate, respectively, the observations at 8 a. m. and 8 p. m., 75th Meridian Time. Within each circle is also given (Chart II) the last three figures of the highest barometric reading or (Chart III) the lowest reading reported at or near the center at that time, and in both cases as reduced to sea level and standard gravity.

Chart IV.—Temperature departures. This chart presents the departures of the monthly mean temperatures from the monthly normals. The normals used in computing the departures were computed for a period of 33 years (1873 to 1905) and are published in Weather Bureau Bulletin "R," Washington, 1908. Stations whose records were too short to justify the preparation of normals in 1908 have been provided with normals as adequate records became available, and all have been reduced to the 33-year interval 1873–1905. The shaded portions of the chart indicate areas of positive departures and unshaded portions indicate areas of negative departures. Generalized lines connect places having approximately equal departures of like sign. This chart of monthly temperature departures in the United States was first published in the MONTHLY WEATHER REVIEW for July, 1909.

Chart V.—Total precipitation. The scale of shades showing the depth is given on the chart. Where the monthly amounts are too small to justify shading and over sections of the country where stations are too widely separated or the topography is too diversified to warrant reasonable accuracy in shading, the actual depths are given for a limited number of representative stations. Amounts less than 0.005 inch are indicated by the letter T, and no precipitation by 0.

Chart VI.—Percentage of clear sky between sunrise and sunset. The average cloudiness at each Weather Bureau station is determined by numerous personal observations between sunrise and sunset. The difference between the observed cloudiness and 100 is assumed to represent the percentage of clear sky, and the values thus obtained are the basis of this chart. The chart does not relate to the nighttime.

Chart VII.—Isobars and isotherms at sea level and prevailing wind directions. The pressures have been reduced to sea level and standard gravity by the method described by Prof. Frank H. Bigelow on pages 13–16 of the REVIEW for January, 1902. The pressures have also been reduced to the mean of the 24 hours by the application of a suitable correction to the mean of the 8 a. m. and 8 p. m. readings at stations taking two observations daily, and to the 8 a. m. or the 8 p. m. observation, respectively, at stations taking but a single observation. The diurnal corrections so applied will be found in the Annual Report of the Chief of the Weather Bureau, 1900–1901, volume 2, Table 27, pages 140–164.

The isotherms on the sea-level plane have been constructed by means of the data summarized in chapter 8 of volume 2 of the annual report just mentioned. The correction, t_0-t or temperature on the sea-level plane minus the station temperature as given by Table 48 of that report, is added to the observed surface temperature to obtain the adopted sea-level temperature.

The prevailing wind directions are determined from hourly observations at the great majority of the stations; a few stations having no self-recording wind-direction apparatus determine the prevailing direction from the daily or twice-daily observations only.

Chart VIII.—Total snowfall. This is based on the reports from regular and cooperative observers and shows the depth in inches and tenths of the snowfall during the month. In general, the depth is shown by lines inclosing areas of equal snowfall, but in special cases figures are also given. Chart VIII is published only when the general snow cover is sufficiently extensive to justify its preparation.

Chart IX.—Average values of pressure, temperature, and prevailing wind directions, and storm tracks over the North Atlantic Ocean, *for the corresponding month of last year.*

[Charts XLIV-93 to XLIV-112, accompanying Henry's report on July floods, p. 466.]

TABLE I.—*Climatological data for Weather Bureau Stations, August, 1916.*

Districts and stations.	Elevation of instruments: Barometer above sea-level.	Elevation of instruments: Thermometer above ground.	Elevation of instruments: Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Pressure: Sea level, reduced to mean of 24 hours.	Pressure: Departure from normal.	Temperature of the air: Mean max.+mean min.÷2.	Temperature of the air: Departure from normal.	Temperature of the air: Maximum.	Temperature of the air: Date.	Temperature of the air: Mean maximum.	Temperature of the air: Minimum.	Temperature of the air: Date.	Temperature of the air: Mean minimum.	Temperature of the air: Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation: Total.	Precipitation: Departure from normal.	Precipitation: Days with 0.01 inch or more.	Wind: Total movement.	Wind: Prevailing direction.	Wind: Maximum velocity: Miles per hour.	Wind: Maximum velocity: Direction.	Wind: Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness.	Total snowfall.	Snow on ground at end of month.
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	*In.*	*In.*		*Miles.*								0–10	*In.*	*In.*
New England.							**68.4**	**+ 1.3**										**81**	**1.87**	**− 2.0**										**4.4**		
Eastport	76	67	85	29.87	29.95	−0.0	60.2	+ 0.5	80	21	69	47	14	52	28	56	54	84	1.82	− 1.4	9	5,629	s.	23	nw.	14	12	9	10	5.2		
Greenville	1,070	6					65.2		91	20	77	40	2	54	36				2.95		12											
Portland, Me.	103	8	115	29.86	29.98	.0	66.4	+ 0.1	89	8	74	49	29	58	28	61	58	76	2.14	− 1.4	10	6,177	s.	25	sw.	23	16	8	7	4.1		
Concord	288	70	79	29.6	29.97	− .0	68.1	+ 2.1	94	21	81	44	29	57	36				3.45	− 0.3	8	3,059	s.	21	w.	14	18	9	4	3.4		
Burlington	404	11	48	29.54	29.96	− .0	69.1	+ 3.0	94	20	80	47	29	59	34				1.06	− 3.0	8	7,247	s.	30	nw.	13	14	10	7	4.5		
Northfield	876	12	60	29.06	29.99	+ .0	65.1	+ 2.3	92	2	78	40	29	53	38	60	58	82	1.94	− 2.0	12	3,998	s.	28	sw.	26	11	10	10	4.9		
Boston	125	115	188	29.85	29.98	− .0	71.8	+ 2.9	95	8	80	54	29	64	25	65	62	77	2.19	− 1.8	9	6,233	sw.	26	w.	14	18	7	6	3.9		
Nantucket	12	14	90	29 97	29 98	− .0	67.3	− 0.7	80	2	74	57	13	61	19	64	62	90	1.05	− 2.0	5	9,974	sw.	36	ne.	11	16	11	4	4.2		
Block Island	26	11	46	29.96	29.99	− .0	68.8	+ 0.1	81	2	74	55	29	63	17	65	64	89	0.57	− 2.9	7	9,617	sw.	36	ne.	10	12	9	10	4.9		
Narragansett Pier		9					68.7	+ 0.2	86	6	77	49	29	6	29				1.50		8		s.				21	4	6			
Providence	160	215	251	29.81	29 98	− .0	70 8	− 0.2	94	8	80	50	29	61	34	65	62	78	0.78	− 3.3	8	7,275	sw.	46	nw.	8	12	13	6	4.4		
Hartford	159	122	140	29 81	29 9	− .0	72.0	+ 3.1	94	8	82	48	29	62	33	65	62	78	3.44	− 1.1	7	5,007	s.	32	nw.	23	11	11	9	5.2		
New Haven	106	117	155	29.87	29.98	− .01	72.0	+ 1.9	94	22	81	50	29	63	27	65	61	73	2.11	− 2.9	9	5,571	s.	36	sw.	8	14	11	6	4.2		
Middle Atlantic States.							**74.1**	**+ 1.3**										**75**	**2.20**	**− 2.2**										**4.5**		
Albany	97	102	115	29.87	29.97	−0.0	72.4	+ 2.9	98	21	82	48	29	63	30	64	60	71	2.32	− 1.6	10	4,927	s.	24	ne.	1	16	12	3	3.4		
Binghamton	871	10	69	29.08	29.99	− .0	70.8	+ 3.3	99	22	83	45	29	59	34				2.80	− 0.4	7	2,501	nw.	21	nw.	13	12	15	4	4.5		
New York	314	414	454	29.66	29.99	− .0	73.6	+ 1.4	94	22	82	55	28	66	24	66	62	73	0.59	− 3.9	7	9,245	s.	45	nw.	8	12	13	6	4.7		
Harrisburg	374	94	104	29.6	30.01	.0	74.6	+ 2.5	97	21	84	54	29	65	28	66	62	72	2.34	− 1.9	8	3,731	sw.	27	nw.	8	11	15	5	4.8		
Philadelphia	117	123	190	29.89	30.01	+ .01	76.4	+ 2.6	97	22	85	59	29	68	26	68	64	70	0.94	− 3.7	7	6,090	sw.	30	n.	28	17	16	3	3.9		
Reading	345	81	98	29.67	30.01	.....	71.6	.....	98	22	85	52	29	64	30	66	63	72	1.56	− 2.9	7	3,777	sw.	27	n.	13	13	11	7	4.6		
Scranton	805	111	119	9.16	30.01	+ .0	71.8	+ 2.5	98	2	84	46	29	60	33	64	60	70	0.67	− 3.6	8	4,030	sw.	31	w.	23	13	16	2	4.1		
Atlantic City	52	37	48	29.95	30.00	.0	73.2	+ 0.6	91	12	79	54	14	67	28	68	65	78	1.21	− 3.1	7	5,376	sw.	18	n.	28	13	10	8	4.8		
Cape May	18	13	49	30.01	30.03	+ .03	73.9	+ 0.5	95	22	82	56	29	66	29				1.03	− 3.2	7	5,155	s.	24	nw.	8	14	14	3	3.7		
Sandy Hook	22	10	57	29.97	29.99	.....	74.0	.....	92	8	81	60	14	67	21	67	65	80	1.16		6	9,269	s.	47	n.	28	13	13	5	4.4		
Trenton	190	159	183	29.79	29.99	.....	74.0	.....	97	22	84	53	29	64	33	66	63	76	1.25	− 4.1	6	6,526	s.	37	nw.	23	14	8	9	4.9		
Baltimore	123	100	113	29.88	30.00	− .01	76.8	+ 2.1	98	22	85	59	29	69	24	68	64	69	0.83	− 3.4	6	4,299	s.	37	nw.	27	14	12	5	4.3		
Washington	112	62	85	29.88	30.00	− .01	75.2	+ 0.7	97	22	85	56	14	65	31	68	66	78	2.83	− 1.6	8	3,245	sw.	52	nw.	27	14	9	8	4.5		
Lynchburg	681	153	188	29.29	30.02	.0	75.3	+ 0.5	93	22	85	55	14	66	29	68	66	79	2.69	− 1.6	14	3,394	w.	37	nw.	21	14	11	6	4.8		
Norfolk	91	170	205	29.92	30.01	+ .01	76.9	+ 0.2	93	12	84	65	31	70	23	69	66	75	2.99	− 3.0	8	7,575	sw.	53	nw.	23	11	13	7	4.8		
Richmond	144	11	52	29.86	30.01	.00	76.1	− 1.4	92	8	86	57	14	66	29	69	67	79	1.55	− 2.9	11	4,328	s.	26	n.	23	14	11	6	4.2		
Wytheville	2,293	49	55	27.73	30.03	+ .03	70.5	0.0	87	6	80	50	25	61	31	65	64	89	9.53	+ 5.0	16	3,251	w.	23	w.	22	7	15	9	5.5		
South Atlantic States.							**79.1**	**+ 1.3**										**81**	**4.25**	**− 1.9**										**5.1**		
Asheville	2,255	70	84	27.76	30.04	+0.02	72.6	+ 2.1	87	6	82	56	21	64	30	66	65	87	2.80	− 2.0	15	3,820	nw.	31	e.	1	3	19	9	6.5		
Charlotte	773	153	161	29.21	30.03	+ .01	77.6	+ 1.0	93	11	87	60	29	69	23	70	68	81	2.70	− 2.8	10	5,647	ne.	38	n.	16	8	16	7	5.2		
Hatteras	11	12	50	30.00	30.01	+ .01	77.8	− 0.4	89	13	82	66	29	73	14	73	72	84	4.54	− 1.3	13	9,500	sw.	47	nw.	16	11	11	9	5.2		
Manteo	12	4	46				77.0	.....	93	13	84	60	15	70					3.87	− 2.1	8		sw.				20	5	6			
Raleigh	376	103	110	29.63	30.01	.00	77.8	+ 1.0	94	1	87	63	29	69	26	70	68	79	6.10	+ 0.2	12	4,465	sw.	36	nw.	23	12	14	5	4.5		
Wilmington	78	81	91	29.95	30.03	+ .02	79.0	+ 1.4	95	16	86	64	20	71	21	73	72	84	2.36	− 4.0	11	4,644	sw.	22	w.	11	11	14	6	4.8		
Charleston	48	11	92	29.98	30.03	+ .0	81.8	+ 1.5	97	13	88	71	30	76	18	75	73	79	3.10	− 3.9	9	6,496	sw.	31	ne.	25	16	10	5	4.1		
Columbia, S. C.	351	41	57	29.66	30.03	+ .02	80.2	+ 0.7	95	16	89	64	31	71	24	72	69	77	4.87	− 1.9	8	4,286	ne.	26	s.	23	11	12	8	5.2		
Augusta	180	62	77	29.83	30.0	+ .01	81.1	+ 2.2	97	17	90	65	21	72	25	73	71	78	2.20	− 3.4	8	3,277	se.	44	nw.	13	9	13	9	5.5		
Savannah	65	150	194	29.96	30.0	+ .0	81.5	+ 2.1	97	17	90	68	24	73	27	74	73	83	7.49	0.0	11	6,840	sw.	48	e.	28	11	15	5	5.0		
Jacksonville	43	200	245	30.00	30.01	+ .02	81.6	+ 1.5	95	17	90	70	20	74	21	74	72	80	6.76	+ 0.6	15	6,986	s.	52	s.	11	8	17	6	4.8		
Florida Peninsula.							**81.6**	**− 0.3**										**78**	**7.97**	**+ 1.0**										**5.3**		
Key West	22	10	64	29.98	30.00	+ .02	82.5	− 1.3	91	18	88	71	31	77	19	76	74	76	5.04	+ 0.4	12	7,315	e.	36	e.	31	15	9	7	4.6		
Miami	25	71	79	30.01	30.04	.....	80.6	− 1.4	91	18	85	70	6	76	15	76	74	79	10.10	+ 2.5	16	6,513	e.	40	s.	25	10	9	12	6.0		
Sand Key	23	39	72	29.95	29.98	.00	82.2	.....	89	24	85	71	2	80	15	77	75	79	2.45	.....	9	10,411	e.	50	se.	1	15	9	7	4.7		
Tampa	35	79	96	30.00	30.04	+ .04	81.7	+ 1.7	95	17	90	69	1	73	22	74	72	79	8.76	+ 0.2	13	3,976	ne.	28	n.	18	5	16	10	5.9		
East Gulf States.							**80.4**	**+ 1.2**										**79**	**3.59**	**− 1.2**										**4.9**		
Atlanta	1,174	190	216	28.84	30.05	+0.04	78.0	+ 1.9	91	17	86	60	25	70	24	70	67	75	3.61	− 0.9	11	5,669	nw.	44	nw.	13	13	9	9	5.1		
Macon	370	78	87	29.64	30.03	+ .02	80.4	+ 2.2	96	17	90	64	22	71	28	72	70	77	1.66	− 2.6	7	3,155	n.	24	sw.	8	13	10	8	5.1		
Thomasville	273	49	58	29.74	30.03	+ .03	81.0	0.0	98	17	90	67	21	72	23	73	71	79	1.01	− 4.0	10	2,647	w.	21	ne.	18	10	13	8	5.3		
Pensacola	56	140	182	29.97	30.02	+ .04	81.0	0.0	92	15	87	69	28	75	21	75	72	80	6.53	− 0.6	7	7,526	sw.	52	sw.	8	7	15	9	5.6		
Anniston	741	9	57	29.28	30.06	+ .07	78.1	+ 1.7	94	18	88	54	25	68	29				3.65	− 0.8	12	2,492	se.	27	w.	13	17	14	0	3.3		
Birmingham	700	11	48	29.30	30.06	+ .07	79.2	− 0.6	93	17	88	57	25	70	29	71	69	80	3.51	− 1.0	8	3,102	sw.	21	s.	4	8	15	8	5.3		
Mobile	57	125	161	29.96	30.02	+ .04	82.0	+ 2.3	95	18	90	68	26	74	23	74	72	79	5.46	− 1.4	11	5,545	sw.	63	ne.	6	13	11	7	4.5		
Montgomery	223	100	112	29.79	30.03	+ .04	80.7	+ 1.0	96	17	90	65	25	72	26	73	70	75	3.28	− 1.0	13	3,559	sw.	36	ne.	6	10	16	5	4.8		
Corinth	469	6					80.0		98	18	91	54	30	69	34				4.49		11						4	25	2			
Jackson	304	5					81.4		98	19	92	58	25	71	30				4.28		11		s.				12	15	4			
Meridian	375	85	93	29.63	30.01	+ .03	80.0	+ 1.5	96	18	89	59	25	71	28	73	71	79	2.97	− 0.6	7	2,619	sw.	21	se.	4	10	17	4	4.5		
Vicksburg	247	65	74	29.76	30.04	+ .06	80.8	+ 1.2	95	18	89	65	25	72	22	74	72	83	3.66	+ 0.1	9	3,540	se.	24	w.	9	10	12	9	5.3		
New Orleans	51	76	84	29.96	30.00	+ .02	83.4	+ 2.4	94	27	90	71	21	77	17	76	74	80	4.89	− 0.7	14	3,775	se.	23	se.	21	12	11	8	5.3		
West Gulf States.							**82.4**	**+ 1.3**										**73**	**3.00**	**± 0.0**										**4.8**		
Shreveport	249	77	93	29.74	30.00	+0.03	83.2	+ 1.8	101	19	93	65	25	73	27	73	70	72	0.55	− 1.7	4	4,300	s.	26	se.	23	17	11	3	3.6		
Bentonville	1,303	11	44	28.66	29.99	+ .02	79.6	+ 3.1	99	13	92	52	24	68	38				3.42	− 0.6	11	1,098	sw.	11	w.	13	18	12	1	3.3		
Fort Smith	457	79	94	29.50	29.96	− .01	85.2	+ 5.8	103	13	96	61	24	74	33	72	66	61	0.23	− 3.4	5	4,811	e.	26	s.	3	11	14	6	4.7		
Little Rock	357	139	147	29.64	30.01	+ .03	81.3	+ 2.1	98	13	91	64	24	72	29	73	71	77	3.59	− 0.1	8	5,239	s.	44	ne.	22	15	9	7	4.3		
Brownsville	57	3	40				82.6	.....	95	21	91	71	25	74	22				5.58		9		se.									
Corpus Christi	20	69	77	29.94	29.96	+ .03	82.6	+ 0.5	92	2	88	73	29	77	17	77	75	83	4.84	+ 2.0	7	8,773	se.	90	e.	18	3	19	9	6.3		
Dallas	512	109	117	29.45	29.98	.....	83.9	.....	100	21	94	66	25	74	27				2.68		5	6,036	se.	34	se.	1	9	19	3	4.8		
Fort Worth	670	106	114	29.26	29.95	+ .01	83.6	+ 0.7	103	21	94	64	24	73	29	70	64	60	3.84	+ 2.0	5	7,123	s.	42	nw.	22	6	18	7	5.6		
Galveston	54	106	114	29.94	30.00	+ .04	83.0	+ 0.4	92	20	87	72	5	78	13	76	74	77	4.14	− 0.9	11	7,359	s.	44	se.	18	13	12	6	4.6		
Houston	138	111	121	29.85	29.99	.....	82.0	− 0.9	95	1	90	68	26	74	23				6.66	.....	14	4,916	se.	37	e.	18	4	18	9	5.8		
Palestine	510	64	72	29.46	29.98	+ .01	82.2	+ 1.7	97	20	92	67	17	72	26	73	70	77	1.86	− 0.4	8	4,419	se.	25	s.	14	10	14	7	5.5		
San Antonio	701	119	132	29.24	29.96	+ .03	82.0	0.0	96	12	91	69	29	72	23	73	70	76	5.07	+ 2.4	7	5,805	sw.	56	se.	19	16	12	3	3.8		
Taylor	582	55	63	29.40	30.01	+ .06	81.3	− 0.4	96	22	91	64	26	71	31				2.44	0.0	9	5,255	s.	40	e.	22	5	22	4	5.2		

TABLE I.—*Climatological data for Weather Bureau Stations, August, 1916*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.				Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.							
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F.*		°*F.*	°*F.*		°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	%	*In.*	*In.*		*Miles.*								0–10	*In.*	*In.*
Ohio Valley and Tennessee							**76.5**	**+ 2.1**											**75**	**3.23**	**− 0.2**									**4.9**		
Chattanooga	762	189	213	29.25	30.05	+0.05	78.4	+ 1.9	94	17	87	60	25	70	26	70	68	76	1.41	− 2.3	9	4,235	w.	30	sw.	12	5	17	9	5.9	.....	.....
Knoxville	996	93	100	29.00	30.03	+ .02	77.0	+ 2.3	90	5	86	56	25	68	27	70	68	81	4.24	+ 0.2	13	2,706	sw	24	nw.	13	5	8	18	6.9	.....	.....
Memphis	399	76	97	29.62	30.04	+ .06	80.8	+ 1.6	95	18	89	63	30	73	22	73	70	76	2.98	− 0.2	9	4,850	sw.	34	nw.	13	18	4	9	4.2	.....	.....
Nashville	546	168	191	29.47	30.04	+ .04	78.4	+ 0.6	93	20	88	57	30	69	30	71	68	77	4.27	+ 0.8	11	4,063	w.	37	nw.	12	10	14	7	4.9	.....	.....
Lexington	989	193	230	28.99	30.04	+ .03	76.0	+ 1.4	93	19	84	54	29	68	23	.....	.....	.....	2.34	− 1.2	10	5,907	sw.	38	w.	11	16	10	5	4.2	.....	.....
Louisville	525	219	255	29.47	30.04	+ .04	78.2	+ 1.7	95	7	87	55	29	70	27	70	66	72	3.06	− 0.4	10	5,974	sw.	54	nw.	26	10	13	8	4.9	.....	.....
Evansville	431	139	175	29.56	30.02	+ .03	79.0	+ 2.0	99	19	88	57	29	70	**28**	72	69	77	4.31	+ 1.1	10	5,704	s.	77	sw.	26	13	13	5	4.4	.....	.....
Indianapolis	822	194	230	29.16	30.03	+ .03	76.6	+ 3.0	96	20	86	53	14	67	28	67	63	69	2.47	− 0.9	8	5,722	sw.	46	w.	22	13	14	4	4.0	.....	.....
Terre Haute	570	96	129	29.40	30.00	.....	77.5	.....	99	20	88	53	29	67	26	69	66	72	3.27	.....	6	4,865	sw.	28	nw.	7	7	19	5	5.3	.....	.....
Cincinnati	628	11	51	29.36	30.02	+ .01	76.3	+ 4.7	96	7	86	52	29	66	30	68	64	72	3.57	+ 0.2	9	3,631	sw.	28	w.	22	12	13	6	4.5	.....	.....
Columbus	824	173	222	29.17	30.02	+ .01	75.8	+ 2.8	96	21	86	54	14	66	28	67	63	68	3.22	0.0	9	5,427	sw.	32	n.	13	19	9	3	3.3	.....	.....
Dayton	899	181	2.6	29.07	30.00	.....	75.4	+ 1.8	96	20	86	51	29	65	28	67	63	71	3.07	+ 0.1	11	4,875	sw.	42	sw.	22	13	9	9	4.6	.....	.....
Pittsburgh	842	353	410	29.13	30.01	.00	74.2	+ 1.7	96	21	84	54	14	65	26	65	61	69	4.73	+ 1.6	11	5,634	sw.	40	nw.	7	8	14	9	5.3	.....	.....
Alaina	1,949	41	50	28.05	30.04	+ .02	70.3	+ 1.5	90	5	82	46	14	58	35	63	62	86	3.13	− 0.5	12	1,867	nw.	21	w.	4	7	8	16	6.9	.....	.....
Parkersburg	638	77	84	29.39	30.04	+ .03	75.2	+ 1.9	94	21	85	53	29	65	31	68	66	80	2.41	− 1.1	8	2,862	se.	28	nw.	26	10	14	7	5.3	.....	.....
Lower Lake Region.							**72.5**	**+ 2.9**											**68**	**2.29**	**− 0.7**									**3.7**		
Buffalo	767	247	280	29.18	29.99	0.00	71.6	+ 2.8	91	6	78	54	13	65	30	63	59	67	1.46	− 1.5	6	9,375	sw.	40	w.	12	16	9	6	4.0	.....	.....
Canton	448	10	61	29.48	29.95	.....	69.2	+ 1.4	96	22	81	46	24	57	40	.....	.....	.....	1.84	− 0.8	9	6,180	sw.	31	n.	20	18	7	6	3.3	.....	.....
Oswego	335	76	91	29.61	29.97	− .02	69.8	+ 1.0	97	22	78	51	29	61	29	63	60	73	1.21	− 1.5	7	5,899	s.	33	ne.	1	16	10	5	3.4	.....	.....
Rochester	523	97	113	29.44	30.00	+ .01	71.9	+ 3.6	98	22	82	51	29	62	34	63	58	68	3.40	+ 0.4	9	4,944	sw.	25	w.	30	17	6	8	3.7	.....	.....
Syracuse	537	97	113	27.36	30.00	+ .01	70.8	+ 2.2	97	22	80	50	29	61	32	64	60	72	3.42	+ 0.1	12	6,284	s.	56	sw.	22	13	11	7	4.5	.....	.....
Erie	714	130	166	29.24	30.00	− .01	72.3	+ 2.4	92	22	81	50	29	64	24	65	61	69	2.69	− 0.6	6	7,898	s.	43	w.	8	12	15	4	4.1	.....	.....
Cleveland	762	190	201	29.21	30.01	.03	72.4	+ 2.0	91	21	80	50	29	65	26	65	61	68	1.36	− 1.8	4	7,561	s.	48	n.	13	14	14	3	3.8	.....	.....
Sandusky	629	62	103	29.34	30.01	.03	74.8	+ 3.3	96	7	84	52	29	66	30	66	61	65	2.28	− 1.1	7	6,898	sw.	44	n.	13	14	15	2	3.5	.....	.....
Toledo	628	203	243	29.35	30.02	+ .02	75.6	+ 4.7	99	20	86	54	28	66	27	65	60	62	2.23	− 0.5	8	7,526	sw.	48	sw.	6	18	13	0	3.0	.....	.....
Fort Wayne	856	113	124	29.11	30.02	.....	74.6	+ 3.5	97	21	85	52	28	64	29	66	61	68	2.10	.....	11	4,845	sw.	27	sw.	19	15	11	5	4.1	.....	.....
Detroit	730	218	245	29.24	30.01	.00	74.6	+ 4.7	96	20	84	55	28	65	26	65	60	67	2.98	+ 0.2	9	6,601	n.	43	ne.	19	16	14	1	3.1	.....	.....
Upper Lake Region.							**69.5**	**+ 3.2**											**73**	**2.66**	**− 0.3**									**4.3**		
Alpena	609	13	92	29.34	30.00	0.00	67.2	+ 3.4	98	20	78	44	27	56	31	62	59	76	1.61	− 1.7	9	7,069	se.	46	nw.	7	7	22	2	4.5	.....	.....
Escanaba	612	54	60	29.32	29.98	− .01	66.2	+ 1.7	88	20	76	42	27	57	26	61	57	75	2.13	− 1.5	10	6,224	s.	43	nw.	7	17	6	8	3.7	.....	.....
Grand Haven	632	54	92	29.33	30.00	+ .01	69.6	+ 1.8	92	21	79	48	27	61	27	64	61	74	5.30	+ 2.7	7	6,070	s.	34	w.	3	19	9	3	3.3	.....	.....
Grand Rapids	707	70	87	29.26	30.01	+ .01	72.8	+ 2.8	97	21	83	48	27	62	30	65	61	71	4.41	+ 1.8	9	3,284	w.	34	w.	10	13	11	7	4.4	.....	.....
Houghton	684	62	99	29.24	29.95	− .02	66.3	+ 3.0	96	6	75	45	30	57	36	.....	.....	.....	2.94	+ 0.1	9	6,733	w.	40	s.	2	11	15	5	4.7	.....	.....
Lansing	878	11	62	29.08	30.01	.....	71.0	+ 2.4	98	20	84	41	28	58	38	64	61	77	1.58	− 1.0	8	2,859	sw.	19	w.	3	16	10	5	3.9	.....	.....
Ludington	637	60	66	29.31	30.00	.....	68.2	.....	89	21	76	48	27	60	21	64	61	76	1.87	.....	9	6,255	s.	43	w.	3	17	11	3	3.5	.....	.....
Marquette	734	77	111	29.19	29.98	.00	66.7	+ 3.2	93	19	77	45	27	56	35	60	55	69	0.93	− 1.9	10	7,579	s.	38	s.	10	8	12	11	5.9	.....	.....
Port Huron	638	70	120	29.32	30.00	.00	71.6	+ 4.3	96	20	82	49	14	61	31	64	61	72	1.95	− 0.7	11	6,522	sw.	30	n.	11	14	17	0	3.9	.....	.....
Saginaw	641	48	82	29.32	30.00	.....	71.9	.....	100	20	84	43	28	59	35	64	60	71	1.25	− 1.6	9	5,111	sw.	31	nw.	3	13	13	5	4.5	.....	.....
Sault Sainte Marie	614	11	61	29.30	29.98	− .01	65.2	+ 4.6	91	20	75	40	28	55	32	60	57	78	3.18	0.0	10	5,512	nw.	42	w.	7	10	14	7	5.4	.....	.....
Chicago	823	140	310	29.14	30.01	+ .01	76.6	+ 5.4	97	21	83	57	27	70	24	67	62	66	1.05	− 1.8	5	7,192	ne.	30	n.	4	18	9	4	3.1	.....	.....
Green Bay	617	109	144	29.32	29.97	− .02	71.4	+ 4.4	96	18	81	46	27	61	30	63	60	72	1.39	− 1.7	7	6,826	sw.	45	n.	2	14	10	7	5.2	.....	.....
Milwaukee	681	119	133	29.28	30.01	+ .01	73.2	+ 4.5	97	20	81	54	27	65	25	65	61	72	6.03	+ 3.2	7	6,134	sw.	42	ne.	3	15	13	3	3.5	.....	.....
Duluth	1,133	11	47	28.76	29.96	− .01	65.1	+ 0.2	90	6	75	43	26	55	32	59	55	75	3.37	− 0.2	13	8,761	w.	44	w.	31	10	17	4	4.8	.....	.....
North Dakota.							**66.2**	**− 0.5**											**70**	**2.49**	**+ 0.2**									**4.0**		
Moorhead	940	8	57	28.96	29.96	0.00	67.2	+ 1.3	95	18	78	42	26	56	37	61	58	80	2.87	− 0.2	11	5,004	se.	24	nw.	10	22	6	3	2.6	.....	.....
Bismarck	1,674	8	57	28.22	29.97	+ .03	67.4	− 0.7	97	16	80	40	13	54	41	58	53	67	1.97	0.0	11	5,685	nw.	36	s.	8	15	7	9	4.6	.....	.....
Devils Lake	1,482	11	44	28.37	29.92	− .02	65.6	+ 0.5	93	18	78	39	26	54	36	57	53	69	3.16	+ 0.4	9	6,334	nw.	46	n.	3	12	10	9	5.1	.....	.....
Grand Forks	835	12	89	.....	.....	.....	65.6	.....	95	18	78	34	26	53	40	.....	.....	.....	3.57	.....	10	.....	nw.	.....	.....	.....	.....	14	14	3	.....	.....
Williston	1,872	41	48	27.98	29.92	− .01	64.8	− 3.1	95	3	78	39	27	52	38	56	50	65	1.95	+ 0.6	8	4,806	se.	42	w.	9	13	15	3	3.9	.....	.....
Upper Mississippi Valley.							**75.6**	**+ 2.7**											**71**	**3.25**	**+ 0.7**									**4.3**		
Minneapolis	918	10	208	28.98	29.94	.....	72.0	.....	97	6	82	49	13	62	34	.....	.....	.....	1.66	− 2.0	8	7,586	s.	32	sw.	21	13	11	7	5.1		
St. Paul	837	201	236	29.08	29.97	0.00	71.6	+ 2.1	96	6	82	47	27	62	33	....	....	....	1.60	− 1.9	11	7,394	sw.	38	w.	21	15	13	3	4.0	.....	.....
La Crosse	714	11	48	29.22	29.98	.00	72.6	+ 2.6	97	18	84	44	27	62	30	.....	.....	.....	4.45	+ 1.0	8	3,125	s.	19	sw.	4	15	8	8	4.1	.....	.....
Madison	974	70	78	28.99	30.01	+ .02	72.8	+ 3.2	98	20	82	52	27	63	25	64	60	68	4.24	+ 1.0	6	5,549	sw.	30	ne.	4	12	10	9	5.1	.....	.....
Wausau	1,247	4	.....	28.69	30.00	.....	68.0	.....	95	20	80	37	27	56	36	.....	.....	.....	1.49	.....	8	.....	se.	.....	.....	.....	.....	15	9	7	4.5	.....	.....
Charles City	1,015	10	49	28.93	29.99	+ .02	71.8	+ 1.1	97	4	84	43	28	59	36	64	61	72	1.01	− 2.4	8	4,385	se.	27	sw.	21	13	16	2	4.0	.....	.....
Davenport	606	71	79	29.34	29.99	+ .01	76.9	+ 3.9	98	5	88	50	27	66	27	67	62	65	1.25	− 2.4	6	4,317	sw.	38	sw.	10	15	7	9	4.5	.....	.....
Des Moines	861	84	97	29.08	29.97	.00	75.8	+ 2.8	102	4	86	49	28	65	32	66	61	65	2.62	− 1.0	5	4,894	s.	35	sw.	21	15	12	4	3.8	.....	.....
Dubuque	698	81	96	29.28	30.01	+ .03	75.0	+ 3.0	99	20	86	48	27	64	30	65	60	67	1.49	− 1.6	5	3,946	s.	22	s.	3	15	9	7	4.5	.....	.....
Keokuk	614	64	78	29.34	30.00	+ .02	77.5	+ 2.9	100	4	88	52	28	67	28	69	66	73	4.71	+ 1.5	11	4,060	sw.	37	sw.	7	12	17	2	4.1	.....	.....
Cairo	356	87	93	29.63	30.00	+ .01	79.4	+ 2.4	96	20	87	59	29	71	22	72	70	79	2.28	− 0.6	6	4,397	s.	30	sw.	22	10	15	6	5.2	.....	.....
Peoria	609	11	45	29.36	30.02	+ .03	76.0	+ 3.5	98	4	87	46	28	65	31	68	65	76	6.03	+ 3.1	7	3,312	s.	22	ne.	10	18	10	3	3.0	.....	.....
Springfield, Ill	644	10	91	29.33	30.00	+ .01	77.3	+ 3.3	98	4	88	52	28	67	26	68	65	73	4.34	+ 1.5	9	4,683	s.	33	w.	11	14	10	7	4.4	.....	.....
Hannibal	534	74	109	29.44	30.00	+ .02	77.7	+ 2.7	99	7	88	48	28	68	28	.....	.....	.....	9.15	+ 5.8	8	5,225	sw.	35	nw.	11	16	10	5	3.8	.....	.....
St. Louis	567	265	303	29.40	30.00	+ .01	78.7	+ 1.5	96	4	87	55	28	70	24	70	67	72	0.69	+ 8.0	10	7,216	s.	44	se.	20	15	13	3	4.3	.....	.....
Missouri Valley.							**75.8**	**+ 2.0**											**69**	**3.48**	**+ 0.1**									**4.1**		
Columbia, Mo	781	11	84	29.18	29.99	+0.02	79.0	+ 4.3	100	12	90	46	28	68	31	.....	.....	.....	2.04	− 1.0	7	4,592	se.	22	n.	11	19	7	5	3.4	.....	.....
Kansas City	963	161	181	28.91	29.96	− .01	78.9	+ 3.1	99	3	89	55	28	69	30	68	63	63	3.82	− 0.9	11	7,123	s.	43	w.	2	17	11	3	3.4	.....	.....
St. Joseph	967	11	49	28.99	29.96	.....	78.3	.....	102	4	89	50	28	68	33	68	64	69	4.24	.....	10	4,718	s.	34	nw.	10	11	13	7	4.5	.....	.....
Springfield, Mo	1,324	98	104	28 63	30.00	+ .03	78.8	+ 4.0	95	12	89	52	28	69	28	68	64	67	4.45	+ 0.1	7	5,950	s.	31	ne.	9	20	10	1	2.8	.....	.....
Iola	984	11	50	28.95	29.96	.....	80.9	+ 4.6	102	3	94	50	28	68	37	.....	.....	.....	2.43	− 1.0	7	4,263	s.	36	ne.	7	15	12	4	3.7	.....	.....
Topeka	983	85	101	.....	.....	.....	79.9	+ 3.9	102	3	91	50	28	68	34	.....	.....	.....	0.78	− 3.5	6	6,607	s.	33	nw.	25	10	17	4	4.2	.....	.....
Drexel	1,299	10	53	28.60	29.97	.....	74.0	.....	97	4	84	44	27	64	33	66	63	73	4.36	.....	8	6,844	s.	31	sw.	21	14	13	4	4.1	.....	.....
Lincoln	1,189	11	84	28.71	29.94	− .01	75.8	+ 1.5	101	4	87	48	28	65	37	66	62	68	6.70	+ 3.0	9	6,712	se.	38	w.	1	14	12	5	4.2	.....	.....
Omaha	1,105	115	127	28.81	29.96	.00	76.5	+ 2.1	100	4	86	52	27	67	31	67	63	68	2.74	− 0.9	9	5,028	s.	26	n.	22	13	12	6	4.5	.....	.....
Valentine	2,598	47	54	27.29	29.96	+ .01	71.2	− 0.1	96	2	84	46	22	59	37	61	57	68	4.45	+ 1.6	10	6,401	s.	40	sw.	15	15	9	7	4.5	.....	.....
Sioux City	1,135	94	164	28.77	29.95	.00	73.6	+ 1.0	96	19	84	43	27	63	39	66	62	70	2.33	− 0.7	9	7,813	s.	70	sw.	6	16	11	4	3.5	.....	.....
Huron	1,306	59	74	28.59	29.97	+ .02	69.8	+ 0.7	97	2	81	42	13	58	36	63	60	76	5.70	+ 3.1	9	6,858	se.	43	nw.	9	13	13	5	4.7	.....	.....
Pierre	1,572	70	75	28.32	29.96	+ .02	71.6	− 1.5	98	9	83	47	13	60	35	62	57	66	4.65	+ 2.6	11	6,156	ne.	32	nw.	16	12	12	7	4.1	.....	.....
Yankton	1,233	49	57	28.64	29.93	− .02	73.8	+ 1.0	94	5	85	46	27	63	33	.....	.....	.....	1.70	− 1.4	8	5,106	e.	28	s.	18	7	17	7	5.5	.....	.....

TABLE I.—*Climatological data for Weather Bureau Stations, August, 1916*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea-level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.				Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	*°F.*	*°F.*	*°F.*		*°F.*	*°F.*		*°F.*	*°F.*	*°F.*	*°F.*	*%*	*In.*	*In.*		*Miles.*							*0–10*	*In.*	*In.*
Northern Slope.							**65.8**	**– 1.0**										**58**	**1.33**	**+ 0.1**									**3.8**		
Billings	3,140	5					66.4		95	1	8	42	1	50					0.83												
Havre	2,505	11	44	27.34	29.9	+0.03	64.9	– 2.0	90	8	79	36	1.	51	45	55	49	64	0.34	– 0.9	7	4,147	sw.	36	sw.	8	23	6	2	2.8		
Helena	4,110	87	114	25.83	29.9	+ .01	65.0	– 1.1	91	1	79	39	2	51	39	51	42	51	1.19	+ 0.5	10	5,999	sw.	31	n.	25	17	12	2	3.3		
Kalispell	2,96	11	34	26.9	29.9	+ .01	61.6	– 1.3	85	31	76	38	2	47	38	52	45	64	1.96	+ 1.2	8	2,823	w.	21	sw.	8	20	6	5	3.9		
Miles City	2,371	26	48	27.46	29.96	+ .03	71.2	– 0.3	10	1	86	46	2	57	44	59	52	60	1.51	+ 0.5	10	3,339	ne.	21	sw.	1	21	9	1	2.3		
Rapid City	3,259	50	58	26 64	29.96	+ .06	67.8	– 1.0	95	8	80	44	2	56	36	56	49	67	2.36	+ 0.2	13	4,985	n.	36	sw.	16	13	11	7	4.5		
Cheyenne	6,088	84	101	24.11	29 96	+ .04	63.8	– 2.0	86	2	76	41	27	52	33	53	47	63	1.26	– 0.2	12	7,095	nw.	47	w.	9	11	15	5	4.7		
Lander	5,37?	60	68	24.71	29 9	+ .03	65 9	+ 0.2	95	1	8	43	28	50	44	50	39	47	0.27	– 0.3	6	3,962	sw.	42	sw.	15	14	13	4	4.1		
Sheridan	3,790	10	47	26.13	29.97	.....	65.9	.....	98	1	83	40	19	49	47	54	44	55	0.13	.....	3	3,586	nw.	38	sw.	8	12	14	5	4.5		
Yellowstone Park	6,200	11	48	23.96	29.97	+ .01	58.0	– 2.9	81	1	74	32	20	42	43	45	36	53	0.70	– 0.3	8	4,966	sw.	35	sw.	7	16	13	2	3.5		
North Platte	2,821	11	51	27.10	29.97	+ .03	74.0	+ 1.8	99	3	87	50	2.	61	35	63	58	68	2.35	– 0.1	12	4,805	s.	30	s.	18	14	13	4	4.0		
Middle Slope.							**77.1**	**+ 1.9**										**60**	**1.85**	**– 0.6**									**4.0**		
Denver	5,29?	106	113	24.81	29.97	+0.05	69.0	– 1.4	89	5	80	51	21	58	30	57	51	6?	1.74	+ 0.4	12	4,985	s.	34	nw.	26	14	10	7	4.1		
Pueblo	4,685	80	86	25.34	29.94	+ .03	71.9	– 0.2	95	2	85	50	28	59	35	59	53	63	3.12	+ 1.6	12	4,114	se.	29	ne.	21	11	18	2	4.2		
Concordia	1,39?	50	58	28.51	29.95	.00	78.7	+ 2.2	103	3	90	50	23	67	40	66	60	60	1.21	– 1.6	10	6,001	s.	22	s.	19	10	15	6	5.0		
Dodge	',509	11	51	27.41	29.95	+ .0?	78.6	+ 2.1	101	3	91	51	28	66	36	65	59	60	2.25	– 0.3	9	7,588	s.	39	se.	20	14	14	3	3.7		
Wichita	1,358	139	158	28.53	29.92	– .03	81.6	+ 4.1	100	3	92	53	28	71	30	68	61	56	2.12	– 1.0	7	9,081	s.	36	sw.	10	18	10	3	3.4		
Altus	1,410	5					84.7		104	2	98	58	28	71	36				0.86		1		s.				23	2	6			
Muskogee	652	4					85.0		105	13	98	56	24	72	43				1.81		5		s.				24	2	5			
Oklahoma	1,214	10	47	28.71	29.96	+ .02	83.0	+ 4.5	102	13	95	56	24	71	38	69	63	60	0.68	– 2.5	5	8,844	s.	35	se.	5	19	10	2	3.3		
Southern Slope.							**78.5**	**– 0.6**										**60**	**4.14**	**+ 2.0**									**4.0**		
Abilene	1,738	10	52	28.17	29.93	+0.01	81.7	+ 0.5	98	13	93	55	24	70	33	67	60	55	0.52	– 1.4	3	7,311	s.	31	se.	19	14	10	7	4.3		
Amarillo	3,676	10	49	26.31	29 96	+ .04	76.6	+ 2.0	97	13	89	55	28	64	28	63	57	62	3.89	+ 1.0	10	7,652	s.	39	s.	20	19	10	2	3.1		
Del Rio	914	64	71	28.9?	29.88	– .02	81.6	– 2.4	94	18	90	67	25	73	24				2.64	+ 0.1	8	7,538	se.	60	se.	19	9	19	3	4.5		
Roswell	3,566	75	85	26.39	29.93	+ .05	74.0	– 2.6	93	14	85	58	29	63	28	63	57	64	9.56	+ 8.1	11	5,015	s.	29	n.	20	13	12	6	4.2		
Southern Plateau.							**75.4**	**– 1.9**										**30**	**1.06**	**0.0**									**3.4**		
El Paso	3,76?	110	133	26.18	29.85	+0.01	77.8	– 0.8	96	10	88	61	20	67	28	64	57	57	3.07	+ 1.4	10	7,407	se.	57	se.	12	12	17	2	4.2		
Santa Fe	7,013	57	66	23.36	29.89	.00	66.8	– 0.2	84	10	77	49	28	56	27	55	49	62	1.67	– 0.7	14	4,608	e.	34	sw.	13	0	30	1	5.4		
Flagstaff	6,908	8	57	23.45	29.89	+ .05	60.7	– 2.1	80	11	74	38	21	48	30				3.29		13		nw.	30	w.	29	8	20	3			
Phoenix	1,108	76	81	28.66	29.78	– .01	87.0	– 2.0	106	7	100	69	21	73	36	69	60	47	0.30	– 0.7	5	3,879	e.	27	e.	14	23	7	1	1.8		
Yuma	141	9	54	29.60	29.74	– .02	89.4	– 0.7	109	31	104	64	18	75	35	71	62	48	0.02	– 0.3	1	3,503	sw.	26	nw.	25	23	8	0	2.1		
Independence	3,910	11	42	25.94	29.84	+ .05	70.8	– 5.6	96	1	88	48	16	54	42	54	38	34	0.22	+ 0.1	3	4,280	se.	29	w.	17	26	4	1			
Middle Plateau.							**68.9**	**– 2.7**										**40**	**0.90**	**+ 0.2**									**2.6**		
Reno	4,532	74	81	25.46	29.88	+0.04	67.2	+ 0.2	94	1	85	38	19	49	45	47	33	38	0.04	– 0.2	1	4,800	w.	36	sw.	17	25	3	3	1.9		
Tonopah	6,090	12	20	24.10	29.90	.....	68.5	.....	90	1	80	40	18	57	29	49	32	30	0.54	+ 0.2	2	6,457	se.	30	se.	2	23	8	0	2.1		
Winnemucca	4,344	18	56	25.60	29.92	+ .04	66.4	– 4.4	96	2	86	30	18	46	51	48	31	35	0.11	– 0.1	2	3,967	ne.	27	sw.	7	24	5	2	1.7		
Modena	5,479	10	43	24.65	29.90	+ .04	65.8	– 2.8	88	23	81	43	10	59	40	51	39	49	1.97	+ 0.1	7	7,615	sw.	47	s.	17	19	10	2	3.0		
Salt Lake City	4,360	147	189	25.61	29.89	– .02	72.9	– 2.6	95	1	84	51	19	62	31	56	43	40	0.60	– 0.2	7	6,179	se.	37	se.	5	20	8	3	2.7		
Grand Junction	4,602	82	96	25.41	29.93	+ .03	72.4	– 3.7	92	1	84	54	31	61	32	57	47	47	2.16	+ 1.1	8	5,632	se.	35	sw.	9	14	13	4	4.0		
Northern Plateau.							**69.7**	**– 0.7**										**43**	**0.76**	**+ 0.4**									**2.6**		
Baker	3,471	48	53	26.45	30.01	+0.06	63.6	– 1.3	90	30	80	35	19	47	43	50	41	51	1.08	+ 0.7	6	4,531	se.	28	sw.	12	23	7	1	2.3		
Boise	2,739	78	86	27.11	29.91	– .02	70.4	– 1.4	96	31	86	39	19	55	3?	54	39	38	0.45	+ 0.3	2	3,442	nw.	31	w.	12	21	7	3	2.4		
Lewiston	757	40	48	29.14	29.93	– .02	72.3	– 1.2	100	27	89	45	19	56	4?				1.41	+ 1.0	6	1,849	e.	18	nw.	15	22	7	2	2.1		
Pocatello	4,477	60	68	25.49	29.90	– .02	68.8	– 1.7	96	1	83	42	20	54	4?	51	37	37	0.95	+ 0.4	6	5,880	se.	46	sw.	17	18	9	4	3.4		
Spokane	1,929	101	110	27.93	29.94	– .01	69.0	+ 1.1	96	29	84	45	20	54	4?	54	43	48	0.4?	0.0	3	3,713	sw.	28	sw.	18	19	9	3	3.3		
Walla Walla	991	57	65	28.86	29.92	– .04	74.0	+ 0.2	102	28	88	47	19	60	3?	57	44	39	0.1?	– 0.3	3	3,253	s.	18	sw.	12	22	7	2	2.3		
North Pacific Coast Region.							**62.6**	**+ 0.7**										**76**	**0.2?**	**– 0.6**									**4.5**		
North Head	211	11	56	29.82	30.04	+0.01	56.8	– 1.1	71	2?	60	50	21	54	20	55	54	91	0.3?	– 0.3	9	9,020	nw.	37	nw.	14	8	6	17	6.2		
Seattle	125	215	250	29.90	30.04	+ .04	63.6	+ 0.5	89	25	72	48	19	55	30	57	52	72	0.1?	– 0.4	4	4,477	n.	21	n.	14	15	6	10	4.4		
Tacoma	213	113	120	29.81	30.03	+ .01	63.9	+ 0.9	90	25	74	45	19	54	33	57	5?	73	0.2?	– 0.5	2	3,360	n.	19	w.	7	11	13	7	4.7		
Tatoosh Island	109	7	57	29.94	30.04	+ .04	55.2	– 0.1	77	24	59	48	20	51	25	54	53	93	0.1?	– 1.9	6	6,734	s.	32	s.	11	12	7	12	5.2		
Medford	1,425	4					71.3		106	25	90	41	19	52	51				0.66		3		e.				19	8	4			
North Yakima	1,071	4					70.6		94	24	85	44	19	56	39				T.		0		nw.				23	5	3			
Portland, Oreg	153	68	106	29.83	29.99	– .02	68.0	+ 2.1	96	24	78	46	19	58	32	60	54	65	0.2?	– 0.4	3	3,847	nw.	18	nw.	3	13	12	6	4.1		
Roseburg	510	9	57	29.46	30.00	.00	68.2	+ 2.0	101	24	84	42	20	53	46	59	53	64	0.3?	0.0	2	2,308	n.	15	n.	19	24	5	2	2.4		
Middle Pacific Coast Region.							**64.5**	**– 0.3**										**61**	**0.12**	**+ 0.1**									**3.4**		
Eureka	62	73	89	29.95	30.02	+0.02	56.0	+ 0.2	69	31	60	46	18	52	19	53	51	87	0.12	0.0	2	4,229	n.	24	n.	1	7	10	14	6.2		
Mount Tamalpais	2,375	11	18	27.51	29.94	+ .01	67.4	+ 1.5	92	23	76	46	17	59	30	54	41	43	0.27	+ 0.3	3	11,048	nw.	66	nw.	17	24	6	1	1.3		
Point Reyes Light	490	7	18	29.40	29.92	.....	53.0	– 1.5	74	20	57	46	7	49	25				0.03		1	17,246	nw.	67	nw.	17	7	3	21	7.5		
Red Bluff	332	50	56	29.50	29.84	– .02	79.4	– 1.6	113	24	94	56	18	65	43	60	43	35	T.	0.0	0	3,403	se.	22	nw.	17	26	1	4	1.5		
Sacramento	69	106	117	29.80	29.87	+ .02	71.8	– 0.3	100	2	87	50	9	56	42	59	50	56	T.	0.0	0	6,048	s.	26	sw.	10	28	2	1	1.2		
San Francisco	155	209	213	29.77	29.94	+ .02	58.5	+ 0.5	84	20	65	48	7	52	27	53	51	84	0.29	+ 0.3	3	8,806	sw.	38	sw.	3	13	14	4	3.7		
San Jose	141	12	110	29.81	29.96	.....	65.6	– 1.1	92	20	79	44	18	52	43				0.01	0.0	1	4,430	nw.	24	nw.	17	25	6	0	2.1		
South Pacific Coast Region.							**69.2**	**– 1.3**										**68**	**0.02**	**0.0**									**2.5**		
Fresno	327	89	98	29.50	29.84	+0.02	78.2	– 3.0	103	3	94	52	18	62	39	59	44	37	0.08	+ 0.1	2	5,751	nw.	26	nw.	17	27	4	0	1.2		
Los Angeles	338	159	191	29.5?	29.90	+ .02	68.6	0.0	96	1	79	54	8	59	32	61	57	76	T.	0.0	0	3,682	sw.	16	sw.	18	25	5	1	2.2		
San Diego	87	62	70	29.8	29.89	.00	67.0	– 1.7	84	1	72	58	21	62	18	62	60	84	0.01	0.0	1	4,378	nw.	17	nw.	1	18	13	0	3.2		
San Luis Obispo	201	32	40	29.7?	29.96	+ .02	62.9	– 0.6	85	26	75	46	20	51	34	55	52	77	T.	0.0	0	2,619	nw.	20	w.	18	14	17	0	3.5		
West Indies.																																	
San Juan, P. R	82	8	54	29.90	29.98	+0.01	80.4	.....	91	15	85	69	29	76	16	.....	.....	.....	7.58	+ 0.2	19	10,922	e.	92	ne.	22	8	16	7	5.5		
Panama Canal.																																	
Balboa Heights	118	7	97	29.76	29.89	.....	78.1	.....	89	12	83	70	7	73	15	74	73	91	10.53	+ 2.5	2?	5,008	s.	36	s.	28	0	24	7	8.3		
Colon	25	5	71	29.85	29.88	.....	80.7	.....	90	30	87	73	7	75	16	76	75	90	8.34	– 6.6	21	4,866	se.	32	s.	31	0	11	20	8.3		

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during August, 1916, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex.	19			0.39														0.38			
Albany, N. Y.	27	3:42 p. m.	5:15 p. m.	0.91	3:53 p. m.	4:09 p. m.	0.02	0.25	0.47	0.67	0.70										
Alpena, Mich.	6	4:05 p. m.	5:18 p. m.	0.78	4:05 p. m.	4:20 p. m.	0.00	0.15	0.41	0.66											
Amarillo, Tex.	21-22	9:40 p. m.	1:44 a. m.	1.89	10:30 p. m.	11:13 p. m.	0.17	0.25	0.45	0.62	0.81	0.90	0.99	1.08	1.20	1.24					
Anniston, Ala.	12	6:30 p. m.	10:15 p. m.	1.15	6:32 p. m.	6:59 p. m.	0.01	0.19	0.40	0.66	0.79	0.89	0.94								
	13	12:43 p. m.	5:10 p. m.	0.97	12:45 p. m.	1:17 p. m.	0.01	0.10	0.17	0.38	0.61	0.81	0.83	0.92							
	18	3:41 p. m.	4:35 p. m.	0.66	4:04 p. m.	4:18 p. m.	0.01	0.40	0.57	0.61											
Asheville, N. C.	22	1:50 p. m.	3:05 p. m.	1.09	1:57 p. m.	2:23 p. m.	0.01	0.15	0.23	0.65	0.93	1.01	1.04								
Atlanta, Ga.	14	12:12 p. m.	1:40 p. m.	0.45	12:43 p. m.	12:58 p. m.	0.03	0.10	0.25	0.40											
		2:43 p. m.	7:35 p. m.	0.62	2:47 p. m.	2:55 p. m.	0.01	0.25	0.39												
Atlantic City, N. J.	28			0.67														0.39			
Augusta, Ga.	13	5:10 p. m.	8:15 p. m.	0.90	5:14 p. m.	5:31 p. m.	0.01	0.21	0.55	0.73	0.80										
Baker, Oreg.	17			0.73														0.20			
Baltimore, Md.	27			0.33														0.31			
Bentonville, Ark.	3	3:08 p. m.	4:20 p. m.	0.87	3:10 p. m.	3:48 p. m.	0.01	0.12	0.17	0.21	0.29	0.50	0.56	0.64	0.69						
	15-16	9:05 p. m.	12:20 a. m.	1.12	9:08 p. m.	9:53 p. m.	0.01	0.08	0.17	0.28	0.37	0.40	0.49	0.66	0.80	0.89					
Binghamton, N. Y.	26	6:15 p. m.	D. N. p. m.	0.80	6:58 p. m.	7:13 p. m.	0.20	0.16	0.30	0.35											
Birmingham, Ala.	2	3:00 p. m.	5:25 p. m.	0.82	4:00 p. m.	4:25 p. m.	0.03	0.08	0.19	0.42	0.59	0.66									
Bismarck, N. Dak.	20-21			1.25														0.21			
Block Island, R. I.	28			0.27														0.15			
Boise, Idaho.	17			0.41														0.16			
Boston, Mass.	28			1.10														0.64			
Buffalo, N. Y.	27			0.48														0.28			
Burlington, Vt.	23			0.20														0.15			
Cairo, Ill.	22	12:41 p. m.	1:15 p. m.	0.75	12:49 p. m.	1:06 p. m.	0.01	0.32	0.58	0.70	0.73										
Canton, N. Y.	8	8:03 a. m.	11:42 a. m.	0.43	9:24 a. m.	9:34 a. m.	0.05	0.26	0.34												
Charles City, Iowa.	3	10:27 a. m.	11:55 a. m.	0.61	10:48 a. m.	11:16 a. m.	0.02	0.15	0.22	0.24	0.27	0.44	0.52								
Charleston, S. C.	6	D. N. a. m.	D. N. a. m.	0.76	3:48 a. m.	4:06 a. m.	0.27	0.08	0.17	0.34	0.41										
Charlotte, N. C.	16	6:42 p. m.	8:10 p. m.	1.03	6:46 p. m.	7:31 p. m.	0.01	0.16	0.23	0.41	0.62	0.70	0.77	0.80	0.87	0.97					
	24	7:50 p. m.	8:20 p. m.	0.60	7:53 p. m.	8:13 p. m.	0.01	0.16	0.39	0.49	0.57										
Chattanooga, Tenn.	12			0.37														0.30			
Cheyenne, Wyo.	15	2:50 p. m.	3:50 p. m.	0.64	3:07 p. m.	3:22 p. m.	0.03	0.16	0.41	0.58											
Chicago, Ill.	10	6:03 p. m.	8:25 p. m.	0.71	6:37 p. m.	6:45 p. m.	0.20	0.30	0.36												
Cincinnati, Ohio.	8	8:36 a. m.	9:17 a. m.	0.47	8:42 a. m.	8:53 a. m.	0.02	0.17	0.39	0.43											
Cleveland, Ohio.	22	8:12 p. m.	8:37 p. m.	0.47	8:19 p. m.	8:30 p. m.	0.02	0.19	0.43	0.45											
Columbia, Mo.	25-26			0.45														0.37			
Columbia, S. C.	1-2	11:35 p. m.	D. N. a. m.	1.78	11:42 p. m.	12:48 a. m.	0.01	0.16	0.34	0.58	0.72	0.91	1.08	1.15	1.17	1.25	1.29	1.43	1.70		
	29	12:15 p. m.	3:30 p. m.	1.20	12:42 p. m.	1:08 p. m.	0.01	0.36	0.56	0.68	0.83	0.91	0.96								
Columbus, Ohio.	11	11:29 a. m.	11:56 a. m.	0.59	11:34 a. m.	11:45 a. m.	0.01	0.14	0.57	0.58											
Concord, N. H.	23	3:07 p. m.	D. N. p. m.	2.15	7:06 p. m.	7:35 p. m.	0.91	0.08	0.31	0.70	0.82	0.89	0.95								
Concordia, Kans.	7			0.62														0.48			
Corpus Christi, Tex.	29	6:39 a. m.	8:55 a. m.	2.41	6:39 a. m.	6:48 a. m.	0.00	0.14	0.21	0.31	0.52	0.76	0.99	1.14	1.28	1.46	1.65	1.95	2.14		
Davenport, Iowa.	10			0.87														0.58			
Dayton, Ohio.	5	2:43 p. m.	2:57 p. m.	0.28	2:45 p. m.	2:50 p. m.	0.01	0.26	0.27												
Del Rio, Tex.	27-28	9:25 p. m.	2:45 a. m.	0.53	9:27 p. m.	9:47 p. m.	T.	0.17	0.27	0.37	0.43										
Denver, Colo.	12	5:20 p. m.	6:50 p. m.	0.49	6:08 p. m.	6:21 p. m.	0.06	0.12	0.24	0.36	0.42										
Des Moines, Iowa.	12	1:12 p. m.	4:17 p. m.	1.08	1:49 p. m.	2:17 p. m.	0.02	0.17	0.35	0.41	0.58	0.67	0.71								
Detroit, Mich.	7	7:07 p. m.	9:45 p. m.	1.26	7:21 p. m.	7:39 p. m.	0.02	0.12	0.37	0.72	0.91										
Devils Lake, N. Dak.	3	7:50 p. m.	8:30 p. m.	0.77	7:49 p. m.	8:09 p. m.	0.02	0.23	0.33	0.62	0.71										
Dodge City, Kans.	31	6:05 p. m.	7:45 p. m.	0.61	6:55 p. m.	7:05 p. m.	0.13	0.12	0.31												
Dubuque, Iowa.	10	5:05 p. m.	5:55 p. m.	0.48	5:45 p. m.	5:51 p. m.	0.15	0.32	0.33												
Duluth, Minn.	21-22			1.93														0.50			
Durango, Colo.																					
Eastport, Me.	8	D. N. a. m.	6:20 a. m.	0.46	2:36 a. m.	2:41 a. m.	0.06	0.31													
Elkins, W. Va.	5	D. N. a. m.	6:30 a. m.	0.91	5:53 a. m.	6:08 a. m.	0.34	0.15	0.42	0.52											
El Paso, Tex.	12	7:05 p. m.	7:40 p. m.	0.35	7:09 p. m.	7:19 p. m.	0.01	0.05	0.32												
Erie, Pa.	5	11:05 a. m.	12:15 p. m.	0.54	11:24 a. m.	11:54 a. m.	0.03	0.07	0.13	0.22	0.34	0.44	0.50								
Escanaba, Mich.	18	D. N. a. m.	6:30 a. m.	1.35	4:58 a. m.	5:43 a. m.	0.43	0.09	0.23	0.29	0.42	0.53	0.63	0.79	0.86	0.91					
Eureka, Cal.	17			0.10														0.09			
Evansville, Ind.	12	7:00 a. m.	11:10 a. m.	1.09	8:21 a. m.	8:47 a. m.	0.35	0.11	0.14	0.19	0.26	0.45	0.51								
Flagstaff, Ariz.																					
Fort Smith, Ark.	*																	*			
Fort Wayne, Ind.	3-4	10:30 p. m.	3:15 a. m.	0.80	2:26 a. m.	2:46 a. m.	0.20	0.12	0.30	0.42	0.56										
Fort Worth, Tex.	22	4:01 p. m.	7:25 p. m.	2.47	4:07 p. m.	4:50 p. m.	0.03	0.40†	0.97†	1.40†	1.71†	1.90†	1.95†	2.09†	2.16†	2.21†					
Fresno, Cal.	28			0.07														0.05			
Galveston, Tex.	5	7:10 a. m.	2:10 p. m.	1.56	11:45 a. m.	11:58 a. m.	0.96	0.24	0.46	0.52											
	8	D. N. a. m.	8:15 a. m.	1.06	4:20 a. m.	4:56 a. m.	0.09	0.05	0.19	0.33	0.46	0.59	0.73	0.76							
	13	10:40 a. m.	12:05 p. m.	0.82	10:43 a. m.	11:05 a. m.	0.01	0.19	0.35	0.55	0.63	0.66									
Grand Haven, Mich.	3	10:13 a. m.	1:38 p. m.	2.10	11:05 a. m.	11:40 a. m.	0.07	0.07	0.16	0.25	0.45	0.66	0.99	1.24							
	10	3:58 p. m.	7:10 p. m.	1.11	5:14 p. m.	5:34 p. m.	0.02	0.21	0.47	0.87	0.95										
Grand Junction, Colo.	3			0.73														0.37			
Grand Rapids, Mich.	3	10:13 a. m.	1:38 p. m.	2.10	11:05 a. m.	11:40 a. m.	0.07	0.07	0.16	0.25	0.45	0.66	0.99	1.24							
					1:19 p. m.	1:29 p. m.	1.65	0.19	0.44												
	10	3:58 p. m.	7:10 p. m.	1.11	5:14 p. m.	5:34 p. m.	0.02	0.21	0.47	0.87	0.95										
Green Bay, Wis.	3			0.36														0.36			
Hannibal, Mo.	12-13	10:05 p. m.	9:18 a. m.	3.11	10:41 p. m.	11:37 p. m.	0.09	0.07	0.23	0.32	0.42	0.51	0.57	0.62	0.74	0.94	1.11	1.30			
	14-15	6:55 p. m.	8:05 a. m.	3.90	12:20 a. m.	1:57 a. m.	0.80	0.22	0.50	0.61	0.63	0.66	0.70	0.74	0.81	1.01	1.11	1.44	1.80	2.04	
					2:42 a. m.	2:02 a. m.	2.96	0.08	0.30	0.40	0.47										
Harrisburg, Pa.	26			0.82														0.42			
Hartford, Conn.	27	4:29 p. m.	7:05 p. m.	1.50	5:30 p. m.	6:47 p. m.	0.11	0.06	0.19	0.26	0.37	0.46	0.51	0.52	0.53	0.62	0.64	0.94	1.35		
Hatteras, N. C.	9	8:20 p. m.	9:00 p. m.	0.61	8:23 p. m.	8:46 p. m.	0.01	0.15	0.21	0.28	0.49	0.58									
	16-17	6:55 p. m.	D. N. a. m.	1.16	7:06 p. m.	7:21 p. m.	0.01	0.23	0.55	0.92											
	29	5:10 a. m.	1:20 p. m.	1.65	5:22 a. m.	5:50 a. m.	0.01	0.35	0.69	0.81	0.94	1.14	1.22								
Havre, Mont.	16			0.12														0.12			
Helena, Mont.	8	12:40 p. m.	4:20 p. m.	0.64	1:56 p. m.	2:06 p. m.	0.18	0.26	0.34												
Houghton, Mich.	6-7	11:00 p. m.	5:00 a. m.	0.91	11:04 p. m.	11:19 p. m.	0.01	0.19	0.44	0.51											
	21	7:18 p. m.	9:00 p. m.	1.05	8:25 p. m.	8:43 p. m.	0.17	0.15	0.53	0.82	0.87										
Houston, Tex.	8	7:30 a. m.	8:45 a. m.	0.92	8:02 a. m.	8:33 a. m.	0.11	0.13	0.26	0.34	0.42	0.63	0.78	0.81							
Huron, S. Dak.	4	6:37 a. m.	10:50 a. m.	0.82	7:21 a. m.	7:40 a. m.	0.07	0.16	0.38	0.60	0.69										
	9	5:50 p. m.	6:40 p. m.	0.95	6:05 p. m.	6:37 p. m.	0.02	0.17	0.35	0.45	0.59	0.71	0.84	0.93							
	20-21	6:18 p. m.	6:05 a. m.	2.42	7:04 p. m.	7:27 p. m.	0.03	0.27	0.39	0.49	0.55	0.62									
Independence, Cal.	28			0.10														0.09			
Indianapolis, Ind.	8	D. N. a. m.	D. N. a. m.	0.79	2:41 a. m.	2:56 a. m.	0.34	0.17	0.25	0.36											
Iola, Kans.	7	5:35 p. m.	7:45 p. m.	1.17	5:51 p. m.	6:17 p. m.	0.01	0.07	0.12	0.23	0.41	0.70	0.73								
Jacksonville, Fla.	5-6	5:45 p. m.	D. N. a. m.	1.69	11:54 p. m.	12:49 a. m.	0.02	0.17	0.22	0.36	0.52	0.65	0.78	1.05	1.27	1.42	1.54				
	11	4:50 p. m.	6:58 p. m.	0.81	5:03 p. m.	5:36 p. m.	0.03	0.20	0.30	0.47	0.60	0.71	0.75								

* Self-register not working. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during August, 1916, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Kalispell, Mont.	9			1.06														0.35			
Kansas City, Mo.	13–14	10:48 p. m.	D. N. a. m.	1.78	11:49 p. m.	12:40 a. m.	0.29	0.13	0.26	0.34	0.42	0.49	0.52	0.58	0.71	0.85	0.89	0.93			
Keokuk, Iowa.	7	5:25 p. m.	6:50 p. m.	1.12	6:05 p. m.	6:33 p. m.	0.12	0.16	0.38	0.60	0.77	0.93	0.97								
	10–11	10:10 p. m.	3:10 a. m.	0.90	11:56 p. m.	12:17 a. m.	0.16	0.08	0.14	0.33	0.57	0.61									
	11	4:55 p. m.	6:80 p. m.	1.26	4:55 p. m.	5:18 p. m.	0.00	0.59	0.91	1.01	1.09	1.13									
Key West, Fla.	8	7:25 a. m.	3:15 p. m.	1.53	10:23 a. m.	10:53 a. m.	0.10	0.19	0.35	0.52	0.64	0.84	1.08								
Knoxville, Tenn.	17	2:42 p. m.	3:14 p. m.	0.80	2:49 p. m.	3:11 p. m.	0.01	0.15	0.50	0.72	0.77	0.79									
	23	2:15 p. m.	5:15 p. m.	1.05	3:56 p. m.	4:21 p. m.	0.27	0.09	0.25	0.42	0.61	0.73									
La Crosse, Wis.	4	7:47 p. m.	D. N. p. m.	2.08	8:01 p. m.	8:36 p. m.	0.24	0.27	0.46	0.69	0.78	1.07	1.18	1.29							
					10:34 p. m.	11:02 p. m.	1.54	0.15	0.26	0.36	0.42	0.47	0.53								
Lander, Wyo.	5–6			0.14														0.12			
Lansing, Mich.	7			0.63														0.36			
Lewiston, Idaho.	8–9			0.94														0.27			
Lexington, Ky.	15			1.44														0.50			
Lincoln, Nebr.	31–1	11:50 p. m.	6:28 a. m.	1.81	12:47 a. m.	1:02 a. m.	0.13	0.20	0.48	0.60											
	3	1:00 a. m.	4:50 a. m.	0.67	3:22 a. m.	3:34 a. m.	0.07	0.27	0.46	0.54											
	2	6:10 p. m.	10:15 p. m.	0.72	6:25 p. m.	6:56 p. m.	0.01	0.10	0.26	0.34	0.41	0.52	0.57	0.60							
Little Rock, Ark.	22	1:48 p. m.	2:50 p. m.	0.90	1:55 p. m.	2:18 p. m.	0.01	0.16	0.34	0.56	0.73	0.82									
Los Angeles, Cal.	24			T.														T.			
Louisville, Ky.	15	D. N. a. m.	6:15 a. m.	1.25	3:40 a. m.	4:40 a. m.	0 09	0.09	0.11	0.20	0.31	0.42	0.48	0.56	0.66	0.73	0.80	1.09			
Ludington, Mich.	7	5:31 p. m.	6:05 p. m.	0.53	5:32 p. m.	5:54 p. m.	T.	0.19	0.22	0.27	0.45	0.50									
Lynchburg, Va.	24	5:05 a. m.	7:35 a. m.	0.52	5:44 a. m.	5:54 a. m.	0.03	0.17	0.46												
Macon, Ga.	4	5:29 p. m.	6:22 p. m.	0.70	5:32 p. m.	5:52 p. m.	0.01	0.21	0.40	0.53	0.60										
Madison, Wis.	4	11:03 a. m.	11:22 p. m.	0.51	11:05 a. m.	11:19 a. m.	0.01	0.20	0.43	0.50											
	4–5	9:20 p. m.	D. N. a. m.	2.01	10:38 p. m.	11:44 p. m.	0.70	0.10	0.28	0.49	0.62	0.74	0.85	0.89	0.91	0.91	0.94	1.17	1.31		
Marquette, Mich.	7			0.39														0.28			
Memphis, Tenn.	9	7:45 p. m.	8:55 p. m.	1.18	7:45 p. m.	8:15 p. m.	0.00	0.14	0.36	0.61	0.83	0.96	1.04								
	13	2:47 p. m.	7:30 p. m.	0.74	2:51 p. m.	3:22 p. m.	0.02	0.10	0.15	0.21	0.38	0.53	0.61	0.64							
Meridian, Miss.	11	12:35 p. m.	1:20 p. m.	0.58	12:37 p. m.	1:07 p. m.	0.01	0.13	0.23	0.34	0.38	0.42	0.53								
Miami, Fla.	4	10:03 a. m.	12:50 p. m.	1.30	10:20 a. m.	10:46 a. m.	0.08	0.17	0.41	0.76	1.00	1.13	1.16								
					12:49 p. m.			0.08	0.18	0.28	0.47	0.71	0.82	1.00	1.24	1.41	1.63				
								1.93	2.26	2.46	2.60	2.76	3.10	3.35	3.58	3.78	3.88				
	25	12:35 p. m.	9:25 p. m.	6.01			0.02	4.07	4.25	4.44	4.59	4.76	4.88	4.94	4.97	5.04	5.16				
								5.26	5.33	5.41	5.45										
						3:35 p. m.															
Milwaukee, Wis.	3	12:55 p. m.	4:30 p. m.	1.86	1:47 p. m.	3:03 p. m.	0.07	0.19	0.29	0.35	0.39	0.61	0.68	0.70	0.73	0.74	0.88	1.06	1.63		
	10	8:15 a. m.	10:50 a. m.	0.81	8:15 a. m.	8:41 a. m.	0.00	0.16	0.26	0.39	0.52	0.66	0.68								
		3:05 p. m.	5:15 p. m.	0.77	3:15 p. m.	3:28 p. m.	0.01	0.24	0.52	0.58											
Minneapolis, Minn.	10			0.48														0.36			
Mobile, Ala.	4	11:56 a. m.	5:12 p. m.	1.40	3:14 p. m.	3:45 p. m.	0.68	0.13	0.30	0.46	0.54	0.61	0.68	0.71							
Modena, Utah.	29	4:52 p. m.	5:30 p. m.	0.39	4:56 p. m.	5:05 p. m.	0.01	0.24	0.36												
Montgomery, Ala.	2–3	9:50 p. m.	D. N. a. m.	0.96	10:57 p. m.	11:28 p. m.	0.01	0.07	0.26	0.44	0.58	0.76	0.82	0.85							
	6	3:55 p. m.	4:18 p. m.	0.63	3:57 p. m.	4:07 p. m.	0.01	0.35	0.60												
Moorhead, Minn.	9			0.66														0.33			
Mount Tamalpais, Cal.	28			0.15														0.10			
Nantucket, Mass.	28			0.58														0.29			
Nashville, Tenn.	1	2:43 p. m.	8:45 p. m.	2.58	2:48 p. m.	3:12 p. m.	0.01	0.17	0.30	0.66	0.83	0.96									
					4:23 p. m.	5:07 p. m.	1.16	0.08	0.13	0.25	0.35	0.43	0.52	0.63	0.84	0.91					
New Haven, Conn.	10	4:20 p. m.	5:08 p. m.	0.85	4:43 p. m.	4:56 p. m.	0.02	0.28	0.65	0.82											
New Orleans, La.	4	9:47 a. m.	2:20 p. m.	0.98	10:08 a. m.	10:32 a. m.	0.01	0.11	0.33	0.42	0.48	0.54									
New York, N. Y.	8			0.32														0.31			
Norfolk, Va.	5			0.64														0.51			
Northfield, Vt.	8–10			0.89														0.33			
North Head, Wash.	1			0.05														0.03			
North Platte, Nebr.	29			0.59														0.34			
Oklahoma, Okla.	27			0.36														0.17			
Omaha, Nebr.	1	2:20 a. m.	2:15 p. m.	1.00	2:27 a. m.	2:52 a. m.	0.01	0.12	0.21	0.33	0.43	0.52									
Oswego, N. Y.	22			0.19														0.19			
Palestine, Tex.	5			0.53														0.46			
Parkersburg, W. Va.	11			0.55														0.44			
Pensacola, Fla.	6	4:50 p. m.	9:55 p. m.	1.57	5:15 p. m.	6:07 p. m.	0.02	0.13	0.28	0.36	0.46	0.52	0.60	0.66	0.84	1.04	1.19	1.27			
	8	5:35 a. m.	1:50 p. m.	3.08	6:41 a. m.	7:12 a. m.	0.25	0.27	0.65	1.00	1.38	1.81	1.90	1.93							
	18	8:15 p. m.	9:30 p. m.	0.65	8:36 p. m.	8:59 p. m.	0.01	0.08	0.28	0.38	0.49	0.55									
Peoria, Ill.	7	2:22 p. m.	3:55 p. m.	0.85	2:32 p. m.	3:01 p. m.	0.05	0.20	0.38	0.49	0.63	0.69	0.75								
					10:15 p. m.	10:44 p. m.	0.01	0.13	0.41	0.73	0.94	1.03	1.15								
	10–11	10:08 p. m.	4:00 a. m.	3.68	11:16 p. m.	11:50 p. m.	1.20	0.20	0.27	0.29	0.43	0.63	0.80	0.91							
					12:50 a. m.	1:40 a. m.	2.22	0.05	0.18	0.30	0.33	0.42	0.59	0.87	1.05	1.17	1.27				
Philadelphia, Pa.	11–12			0.39														0.25			
Phoenix, Ariz.	12			0.12														0.10			
Pierre, S. Dak.	20–21			3.77														0.69			
Pittsburgh, Pa.	5	3:05 p. m.	5:40 p. m.	1.81	3:11 p. m.	4:16 p. m.	0.01	0.06	0.26	0.44	0.45	0.45	0.45	0.45	0.57	0.71	0.94	1.52	1.67		
	8	1:12 p. m.	4:45 p. m.	0.76	1:15 p. m.	1:32 p. m.	0.02	0.18	0.32	0.52	0.58										
Pocatello, Idaho.	15	2:48 p. m.	4:10 p. m.	0.74	3:30 p. m.	3:49 p. m.	0.08	0.07	0.21	0.48	0.61										
Point Reyes Light, Cal.	13			0.03														0.01			
Port Huron, Mich.	7	5:35 p. m.	8:30 p. m.	1.34	5:42 p. m.	6:40 p. m.	0.01	0.16	0.28	0.40	0.45	0.45	0.45	0.45	0.57	0.58	0.70	1.08			
Portland, Me.	23	5:07 p. m.	5:48 p. m.	0.65	5:21 p. m.	5:35 p. m.	0.01	0.24	0.55	0.63											
Portland, Oreg.	17			0.10														0.08			
Providence, R. I.	27			0.23														0.21			
Pueblo, Colo.	20			1.39														0.58			
Raleigh, N. C.	23–24	10:02 p. m.	D.N. a.m.	2.61	10:12 p. m.	10:44 p. m.	0.01	0.37	0.76	1.22	1.41	1.62	1.74	1.81							
	28	3:57 p. m.	4:17 p. m.	1.05	3:57 p. m.	4:15 p. m.	0.00	0.26	0.70	0.96	1.05										
Rapid City, S. Dak.	16	4:22 p. m.	5:35 p. m.	1.00	4:48 p. m.	5:12 p. m.	0.02	0.15	0.46	0.70	0.85	0.98									
Reading, Pa.	28	8:09 a.m.	8:27 a.m.	0.44	8:09 a.m.	8:16 a.m.	0.00	0.38	0.44												
Red Bluff, Cal.	14			T.														*			
Reno, Nev.	28			0.04														0.01			
Richmond, Va.	16	D.N. a.m.	7:47 a.m.	0.50	3:10 a.m.	3:22 a.m.	0.01	0.23	0.29	0.35											
Rochester, N. Y.	11	6:13 p. m.	7:00 p. m.	0.58	6:17 p. m.	6:37 p. m.	0.02	0.21	0.33	0.46	0.53										
	30	1:42 p. m.	2:30 p. m.	0.56	2:03 p. m.	2:28 p. m.	0.01	0.14	0.20	0.39	0.45	0.55									
Roseburg, Oreg.	17			0.35														0.07			
Roswell, N. Mex.	8	12:52 p. m.	6:55 a.m.	5.57	2:01 a.m.	4:10 a.m.	2.01	0.08	0.19	0.34	0.53	0.72	0.82	0.90	0.97	1.05	1.14	1.40	1.93	2.40	2.78
Sacramento, Cal.	28			T.														T.			
Saginaw, Mich.	18			0.50														0.39			
St. Joseph, Mo.	13–14	7:05 p. m.	6:30 a.m.	2.35	3:01 a.m.	3:22 a.m.	0.82	0.25	0.49	0.54	0.62	0.66									
					5:14 a.m.	5:52 a.m.	1.61	0.15	0.29	0.34	0.37	0.43	0.47	0.56	0.64						
St. Louis, Mo.	11	8:03 p. m.	10:15 p. m.	0.94	8:10 p. m.	8:25 p. m.	0.01	0.27	0.62	0.88											
	12–13	8:38 p. m.	D.N. a.m.	1.97	8:42 p. m.	9:25 p. m.	0.01	0.12	0.35	0.73	1.14	1.36	1.52	1.65	1.78	1.83					
	14	D.N. a.m.	12:20 p. m.	1.52	6:41 a.m.	7:15 a.m.	0.49	0.12	0.39	0.60	0.63	0.67	0.69	0.81							
	14–15	12:25 p. m.	7:30 a.m.	3.88	10:44 p. m.	11:30 p. m.	0.01	0.19	0.62	0.86	0.97	1.07	1.30	1.49	1.72	1.94	1.98				
St. Paul, Minn.	10			0.52														0.42			

[1] July.

* Self-register not working.

† Record partly estimated.

‡ No precipitation occured during month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during August, 1916, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration. From—	Total duration. To—	Total amount of precipitation.	Excessive rate. Began—	Excessive rate. Ended—	Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated: 5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Salt Lake City, Utah	5			0.24																	
San Antonio, Tex	29	4:16 p. m.	6:25 p. m.	2.28	4:20 p. m.	4:57 p. m.	0.02	0.21	0.78	1.31	1.63	1.88	2.10	2.18	2.22			0.21			
San Diego, Cal	24			0.01																	
Sand Key, Fla	2	7:35 a. m.	2:45 p. m.	0.84	8:07 a. m.	8:41 a. m.	0.10	0.06	0.21	0.32	0.39	0.44	0.60	0.69				0.01			
Sandusky, Ohio	11	D. N. a. m.	D. N. a. m.	0.81	2:20 a. m.	2:47 a. m.	0.06	0.06	0.08	0.10	0.27	0.48	0.52								
San Francisco, Cal	13–14			0.22																	
San Jose, Cal	26			0.01														0.12			
San Luis Obispo, Cal	27			T.														0.01			
Santa Fe, N. Mex	15	7:30 p. m.	8:35 p. m.	0.47	7:35 p. m.	7:56 p. m.	0.01	0.17	0.30	0.35	0.41	0.43						T.			
Sault Ste. Marie, Mich	7	6:35 a. m.	9:00 a. m.	1.07	6:42 a. m.	6:55 p. m.	0.01	0.61	0.85	0.92											
	31	3:30 p. m.	4:45 p. m.	0.68	3:50 p. m.	4:04 p. m.	0.04	0.25	0.45	0.54											
Savannah, Ga	24	4:13 p. m.	5:26 p. m.	1.84	4:18 p. m.	5:18 p. m.	0.01	0.19	0.50	0.57	0.58	0.70	0.89	1.05	1.13	1.27	1.39	1.81			
	28	2:54 p. m.	6:30 p. m.	1.95	3:33 p. m.	4:37 p. m.	0.01	0.08	0.12	0.32	0.62	0.79	1.00	1.09	1.25	1.40	1.54	1.76	1.88		
Scranton, Pa	27			0.10														0.08			
Seattle, Wash	18			0.06														0.04			
Sheridan, Wyo	8			0.05														0.05			
Shreveport, La	23			0.24														0.16			
Sioux City, Iowa	6–7	9:00 p. m.	D. N. a. m.	1.17	9:10 p. m.	9:30 p. m.	0.05	0.23	0.54	0.76	0.84										
	9–10	12:20 p. m.	D. N. a. m.	0.58	10:29 p. m.	10:47 p. m.	0.03	0.10	0.26	0.35	0.41										
Spokane, Wash	8			0.34														0.14			
Springfield, Ill	3	3:40 p. m.	6:35 p. m.	0.55	3:51 p. m.	4:00 p. m.	0.01	0.24	0.49												
	7	5:45 p. m.	D. N. p. m.	0.92	5:50 p. m.	6:26 p. m.	0.01	0.11	0.20	0.21	0.28	0.48	0.62	0.71	0.72						
	2	3:17 p. m.	5:40 p. m.	1.85	3:44 p. m.	4:31 p. m.	0.01	0.16	0.23	0.43	0.57	0.73	0.90	1.08	1.43	1.70	1.78				
Springfield, Mo	9	12:25 p. m.	1:45 p. m.	1.11	12:31 p. m.	1:30 p. m.	0.01	0.15	0.35	0.63	0.64	0.64	0.65	0.74	0.80	0.82	0.90	1.08			
	9	3:02 p. m.	7:30 p. m.	0.90	3:40 p. m.	3:55 p. m.	0.12	0.25	0.51	0.62											
Syracuse, N. Y	8			0.61														0.55			
Tacoma, Wash	17			0.18														0.09			
Tampa, Fla	4	4:55 p. m.	8:15 p. m.	1.67	5:02 p. m.	6:19 p. m.	0.01	0.16	0.39	0.52	0.65	0.73	0.87	1.00	1.10						
	6	2:20 p. m.	4:45 p. m.	1.64	2:39 p. m.	3:39 p. m.	0.02	0.19	0.43	0.52	0.56	0.58	0.63	0.73	0.84	0.98	1.24	1.50			
	9	2:02 p. m.	6:05 p. m.	1.88	2:06 p. m.	2:46 p. m.	0.01	0.05	0.30	0.73	1.07	1.31	1.55	1.66	1.71						
Tatoosh Island, Wash	2			0.05														0.05			
Taylor, Tex	22	5:25 p. m.	6:40 p. m.	0.85	5:59 p. m.	6:19 p. m.	0.02	0.18	0.57	0.71	0.79										
Terre Haute, Ind	14–15	7:05 p. m.	8:20 a. m.	1.54	4:48 a. m.	5:05 a. m.	0.78	0.10	0.26	0.36	0.42										
Thomasville, Ga	6	9:48 a. m.	11:20 a. m.	0.60	9:52 a. m.	10:10 a. m.	0.01	0.16	0.31	0.31	0.40										
Toledo, Ohio	8	12:03 a. m.	12:11 a. m.	0.55	1:15 a. m.	12:34 a. m.	0.03	0.12	0.24	0.36	0.43	0.49									
Tonopah, Nev	27			0.39														0.14			
Topeka, Kans	14			0.19														0.16			
Valentine, Nebr	20–21	3:55 p. m.	D. N. a. m.	3.33	4:19 p. m.	4:36 p. m.	0.03	0.12	0.44	0.59	0.64										
Vicksburg, Miss	8	5:20 p. m.	9:20 p. m.	2.13	6:31 p. m.	7:20 p. m.	0.02	0.17	0.23	0.30	0.51	0.86	1.12	1.19	1.27	1.33	1.40				
Walla Walla, Wash	17			0.12														0.08			
Washington, D. C	*6	1:20 p. m.	3:10 p. m.	1.46														1.13*			*1.46
	27	4:25 p. m.	5:30 p. m.	0.42	4:29 p. m.	4:38 p. m.	0.01	0.13	0.38												
Wichita, Kans	16			0.91														0.51			
Williston, N. Dak	1	8:55 p. m.	9:27 p. m.	0.38	9:08 p. m.	9:18 p. m.	0.01	0.27	0.37												
Wilmington, N. C	24	2:10 p. m.	3:04 p. m.	0.51	2:52 p. m.	3:02 p. m.	0.05	0.19	0.45												
Winnemucca, Nev	17			0.05														0.04			
Wytheville, Va	6	6:41 p. m.	8:25 p. m.	2.62	6:45 p. m.	7:48 p. m.	0.02	0.08	0.18	0.22	0.25	0.32	0.57	0.95	1.23	1.51	1.83	2.43	2.59		
	16	12:14 p. m.	1:24 p. m.	0.96	12:20 p. m.	12:45 p. m.	0.01	0.18	0.35	0.41	0.53	0.71									
	22	2:40 p. m.	5:00 p. m.	2.50	2:42 p. m.	3:20 p. m.	0.01	0.21	0.47	1.02	1.57	1.95	2.18	2.31	2.40						
Yankton, S. Dak	6–7	11:10 p. m.	12:10 a. m.	0.61	11:15 p. m.	11:35 p. m.	0.01	0.10	0.22	0.44	0.58										
Yellowstone Park, Wyo	7–8			0.46														0.18			

* Self-register not working. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE III.—*Data furnished by the Canadian Meteorological Service, August, 1916.*

Stations.	Altitude above M. S. L.* Jan. 1, 1916.	Pressure.			Temperature of the air.						Precipitation.		
		Station, reduced to mean of 24 hours.	Sealevel, reduced to mean of 24 hours.	Departure from normal.	Mean max.+ mean min.÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125	29.67	29.80	−0.16	59.2	−0.6	67.8	50.6	80	42	2.25	−1.83	.....
Sydney, C. B. I.	48	29.90	*29.94*	− *.01*	65.3	+2.0	76.3	54.4	88	45	3.42	−0.20	.....
Halifax, N. S.	88	29.86	*29.96*	*.00*	65.5	+1.9	76.2	54.9	80	44	1.31	−3.04	.....
Yarmouth, N. S.	65	29.89	29.96	− .01	60.6	+0.4	68.2	53.1	79	42	1.42	−2.59	.....
Charlottetown, P. E. I.	38	29.88	29.92	− .02	66.3	+2.0	74.2	58.3	82	47	1.64	−2.10	.....
Chatham, N. B.	28	29.89	*29.91*	− *.02*	67.5	+4.3	78.3	56.8	94	43	2.85	−1.19	.....
Father Point, Que.	20	29.86	29.88	− .03	57.3	+1.7	65.7	48.9	77	44	2.18	−0.87	.....
Quebec, Que.	296	29.62	29.94	+ .01	66.6	+3.5	75.9	57.4	89	47	1.96	−1.87	.....
Montreal, Que.	187	29.73	29.93	+ .02	70.2	+3.8	79.3	61.2	92	54	1.46	−2.11	.....
Stonecliffe, Ont.	489	29.34	*29.94*	− *.02*	67.2	+4.0	80.4	54.1	96	42	2.75	−0.20	.....
Ottawa, Ont.	236	29.68	*29.94*	− *.02*	69.3	+4.5	80.2	58.3	94	46	1.81	−1.22	.....
Kingston, Ont.	285	29.66	29.96	− .02	68.6	+1.6	76.9	60.3	88	47	2.67	+0.29	.....
Toronto, Ont.	379	29.58	*29.97*	− *.02*	71.9	+5.9	83.9	60.0	98	46	1.56	−1.20	.....
White River, Ont.	1,244	28.62	*29.91*	− *.05*	58.9	+2.5	73.7	44.2	90	24	2.97	−0.33	.....
Port Stanley, Ont.	592	29.38	30.01	+ .01	69.3	+3.4	79.5	59.2	89	47	5.86	−3.44	.....
Southampton, Ont.	656	29.30	.....	.....	68.5	+4.7	77.2	59.9	91	46	1.76	−0.49	.....
Parry Sound, Ont.	688	29.29	29.97	− .01	69.6	+6.1	81.9	57.3	98	45	2.00	−0.72	.....
Port Arthur, Ont.	644	29.24	29.95	− .01	63.0	+3.5	73.0	53.0	84	39	5.54	+2.79	.....
Winnipeg, Man.	760	29.09	29.91	− .03	64.8	+1.4	76.3	53.4	93	38	2.35	−0.32	.....
Minnedosa, Man.	1,690	28.13	29.92	− .02	60.7	+1.3	73.8	47.7	91	34	1.18	+0.08	.....
Qu'Appelle, Sask.	2,115	27.66	29.88	− .05	60.8	−0.7	74.6	47.0	89	33	2.99	+1.35	.....
Medicine Hat, Alberta.	2,144	27.64	*29.88*	− *.04*	65.2	−0.5	79.7	50.8	90	38	1.69	+0.02	.....
Swift Current, Sask.	2,392	27.36	*29.89*	− *.04*	60.6	−3.4	75.1	46.1	88	32	2.54	+0.63	.....
Calgary, Alberta.	3,428	26.45	*29.93*	+ *.02*	60.5	+1.1	73.7	47.2	85	39	2.03	−0.11	.....
Banff, Alberta.	4,521	25.42	29.93	+ .02	55.4	−0.9	70.1	40.7	80	33	3.30	−0.77	1.0
Edmonton, Alberta.	2,150	27.64	*29.88*	− *.04*	58.1	−0.7	70.0	46.2	81	32	3.70	+1.57	.....
Prince Albert, Sask.	1,450	28.34	*29.87*	− *.05*	60.2	+1.3	73.0	47.4	85	30	1.66	−0.49	.....
Battleford, Sask.	1,592	28.18	*29.90*	− *.01*	60.3	−2.3	72.5	48.1	84	34	4.70	+2.34	.....
Kamloops, B. C.	1,262	28.71	*29.97*	+ *.06*	68.2	−0.4	83.2	53.2	94	45	0.39	−0.70	.....
Victoria, B. C.	230	29.76	30.01	.00	59.1	+0.4	67.2	51.1	86	48	T.	−0.60	.....
Barkerville, B. C.	4,180	25.77	30.07	+ .17	52.3	+4.0	65.0	39.6	76	30	0.56	−2.54	.....
Hamilton, Bermuda.	151	29.94	30.10	.00	78.1	−1.5	83.1	73.1	85	69	5.42	−0.66	.....

* The altitudes given were furnished by the Director, Canadian Meteorological Service, Mar. 9, 1916, and refer to cisterns of barometers at the respective stations. Where sea-level pressures and departures are *italicized* new reduction factors are in course of computation.—C. A., jr.

Chart I. Hydrographs of Several Principal Rivers, August, 1916.

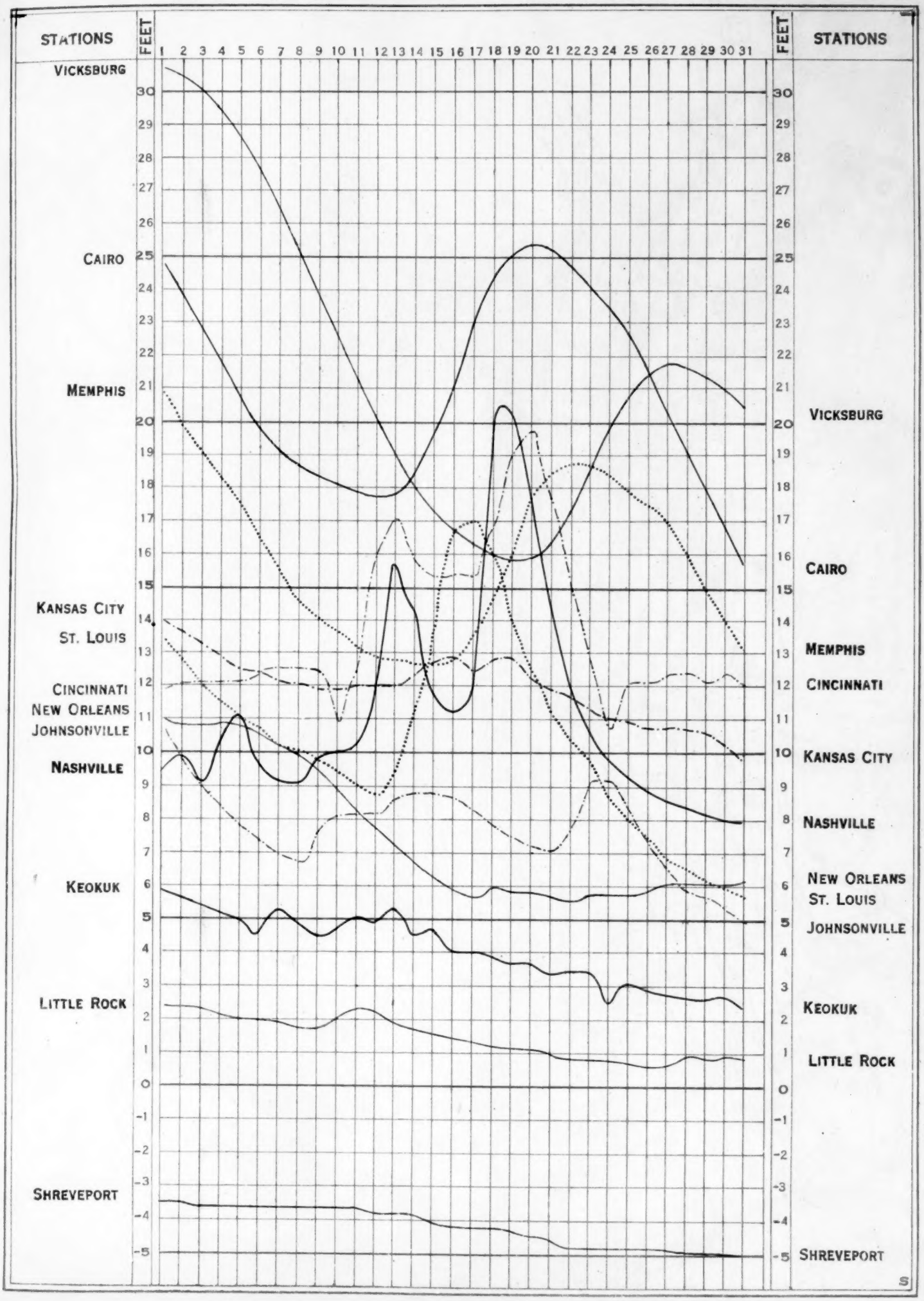


Chart II. Tracks of Centers of High Areas, August, 1916.

(Plotted by R. H. Weightman.)

Chart III. Tracks of Centers of Low Areas, August, 1916.

(Plotted by R. H. Weightman.)

Chart III. Tracks of Centers of Low Areas, August, 1916.

(Plotted by R. H. Weightman.)

Chart IV. Departure (°F.) of the Mean Temperature from the Normal, August, 1916.

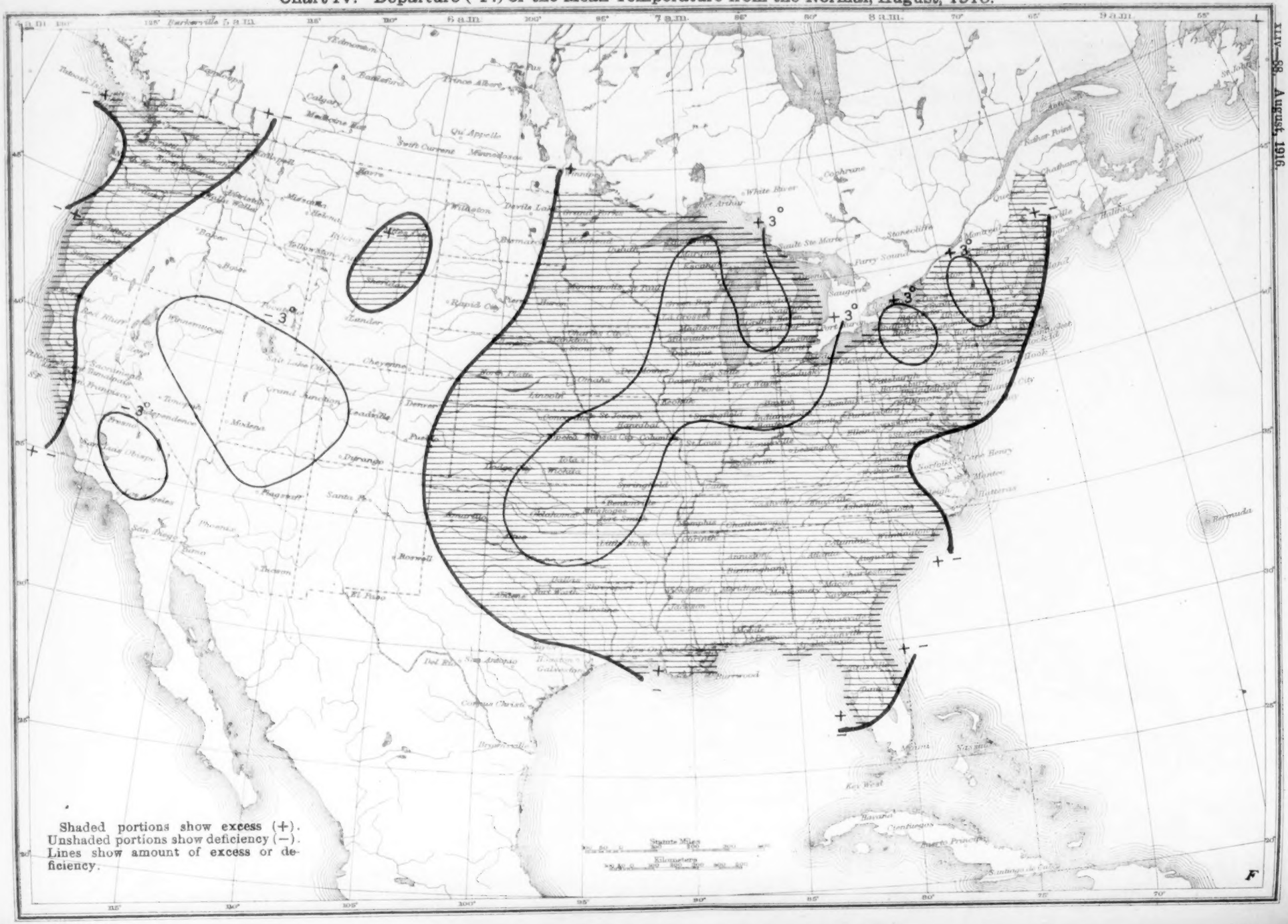


Chart V. Total Precipitation, August, 1916.

Chart VI. Percentage of Clear Sky between Sunrise and Sunset, August, 1916.

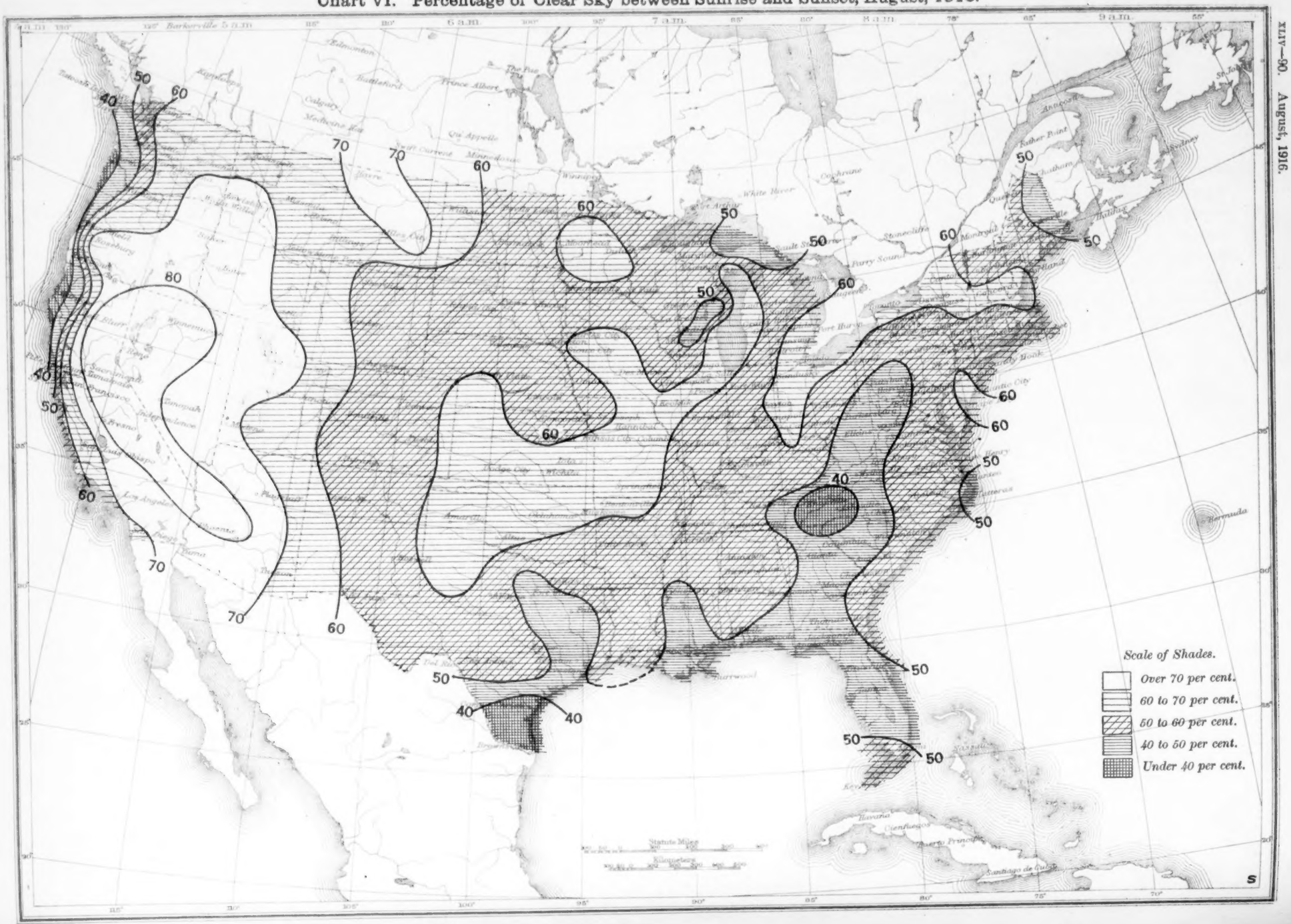


Chart VII. Isobars and Isotherms at Sea Level; Prevailing Winds, August, 1916.

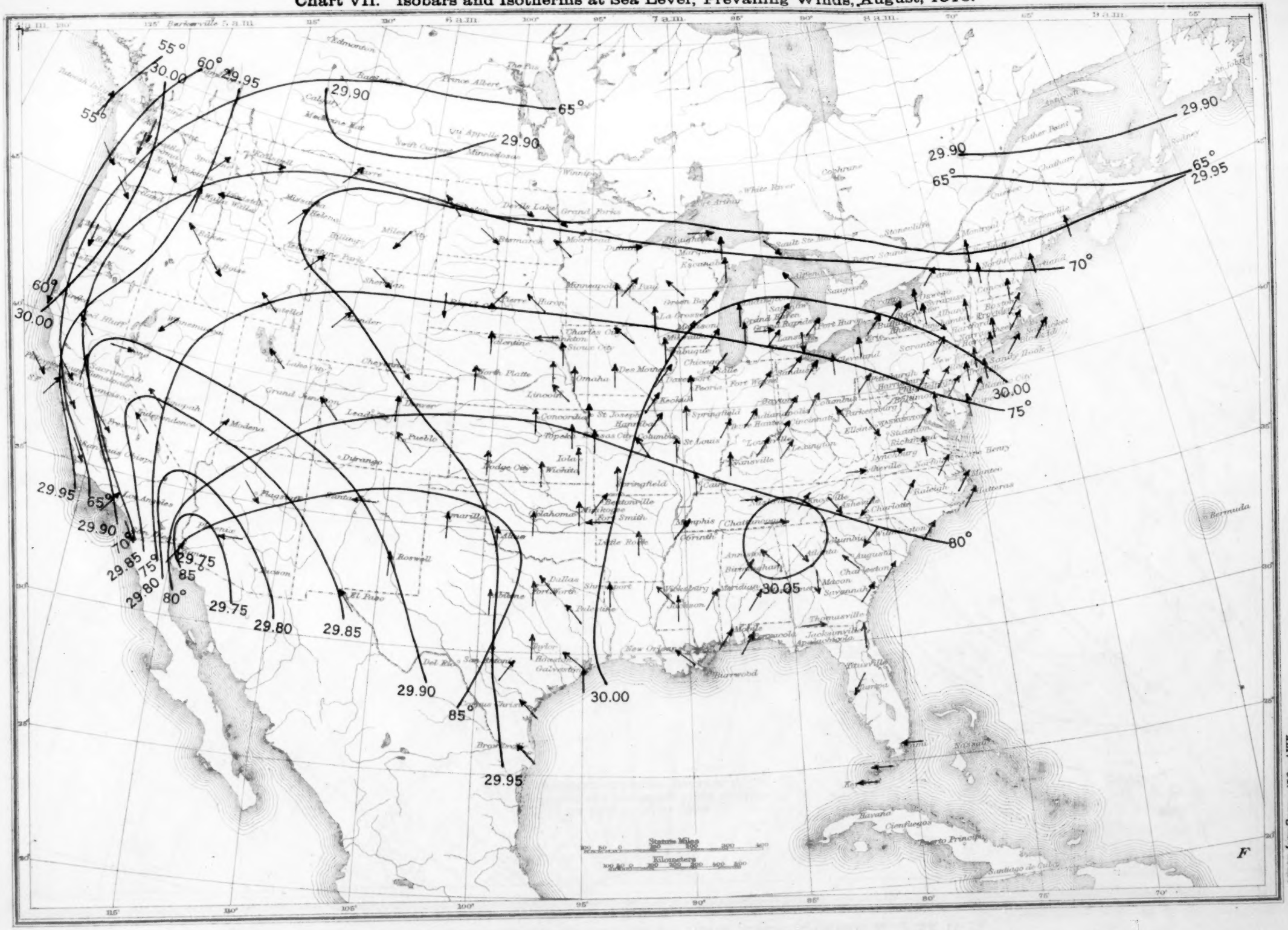
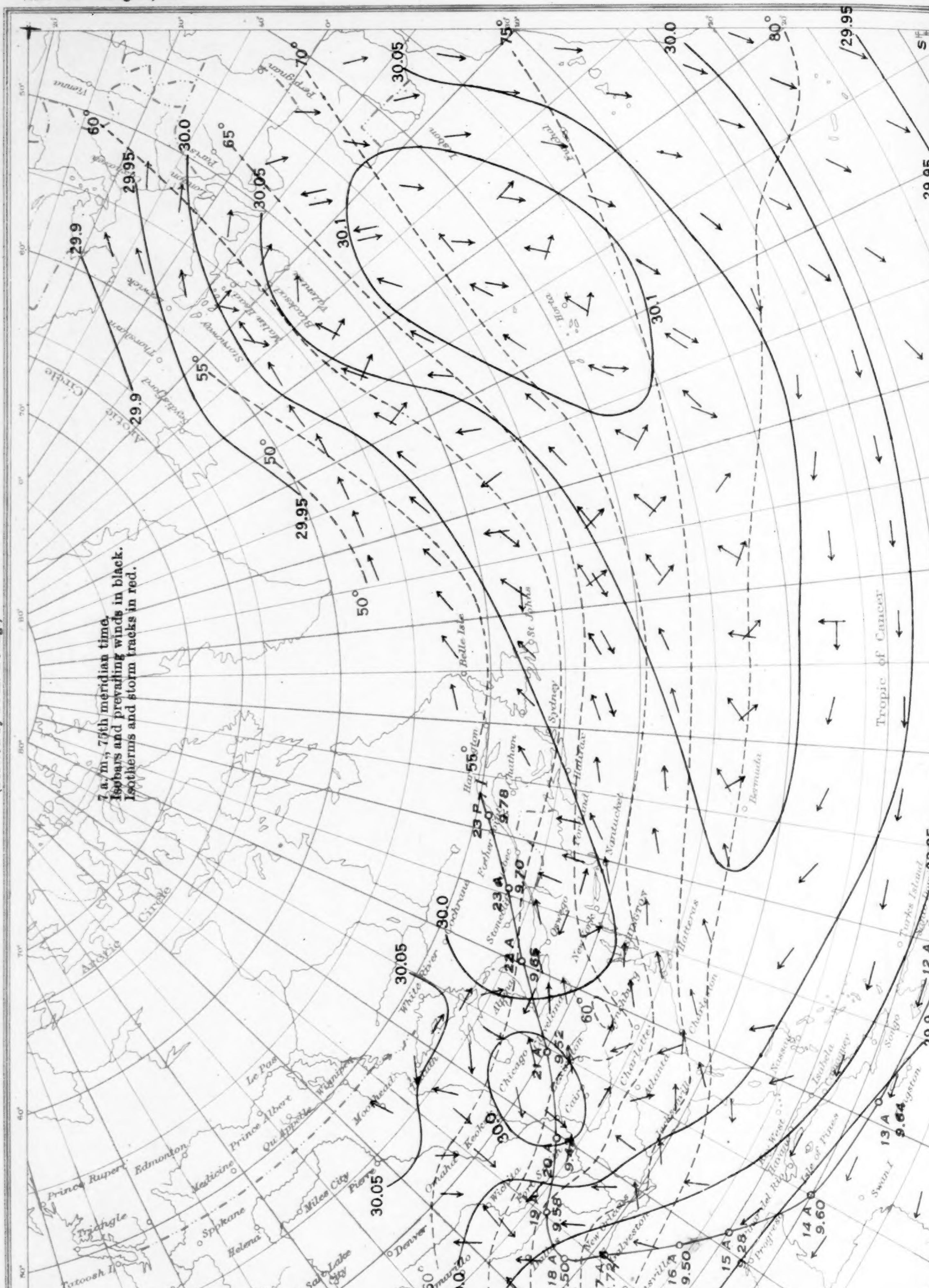
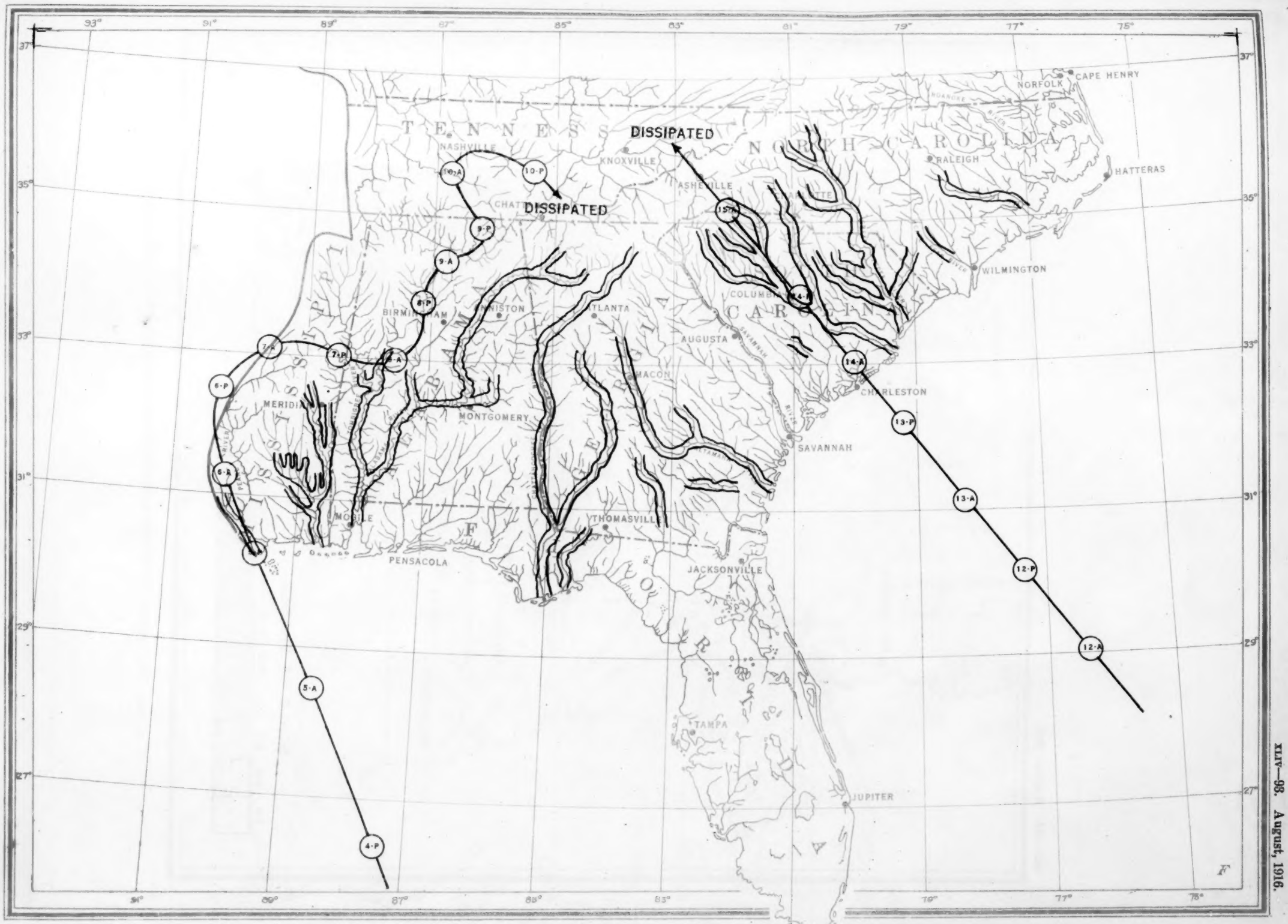


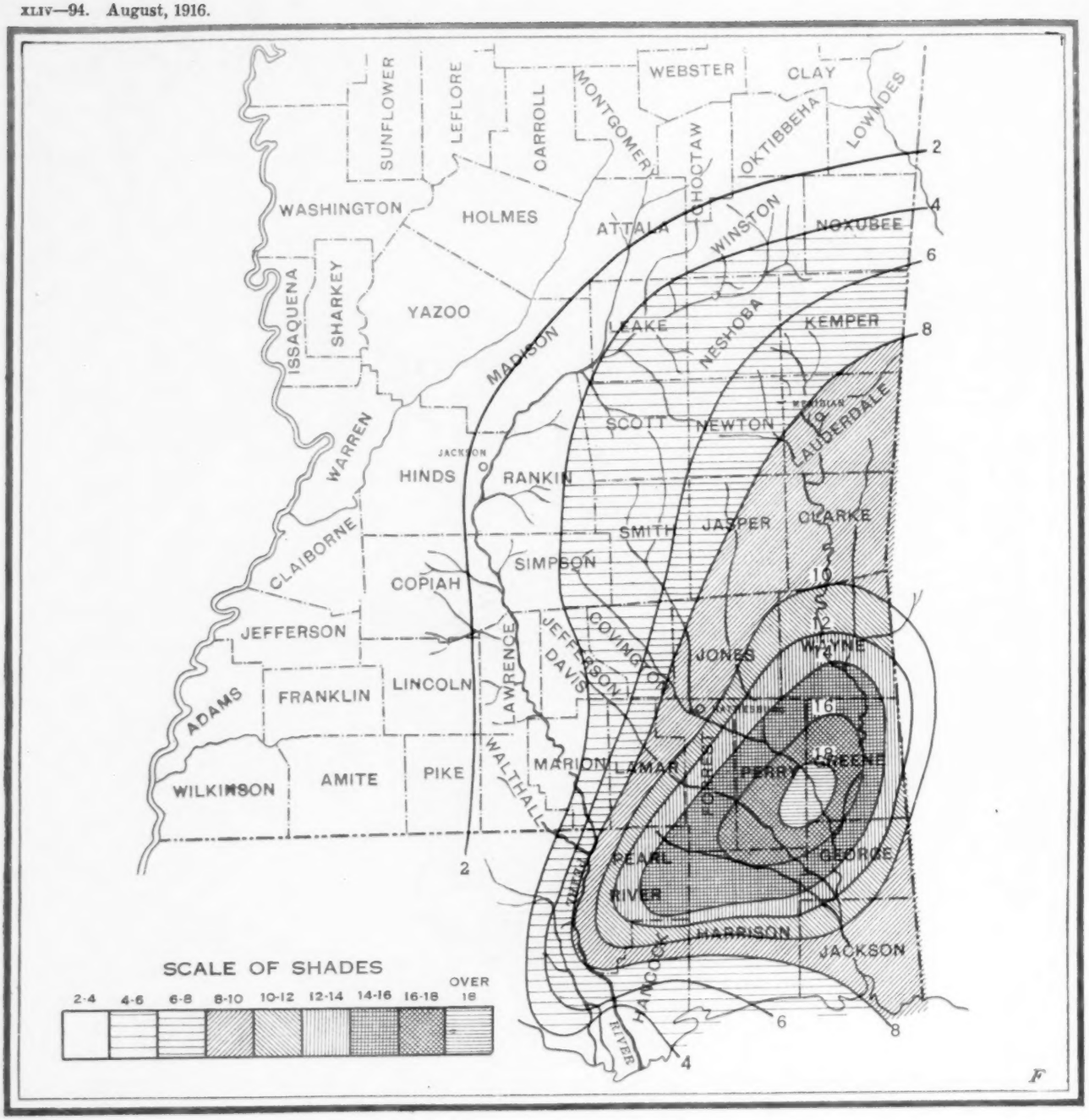
Chart IX. Means of Meteorological Data for North Atlantic Ocean, August, 1915.

(Plotted by F. A. Young.)

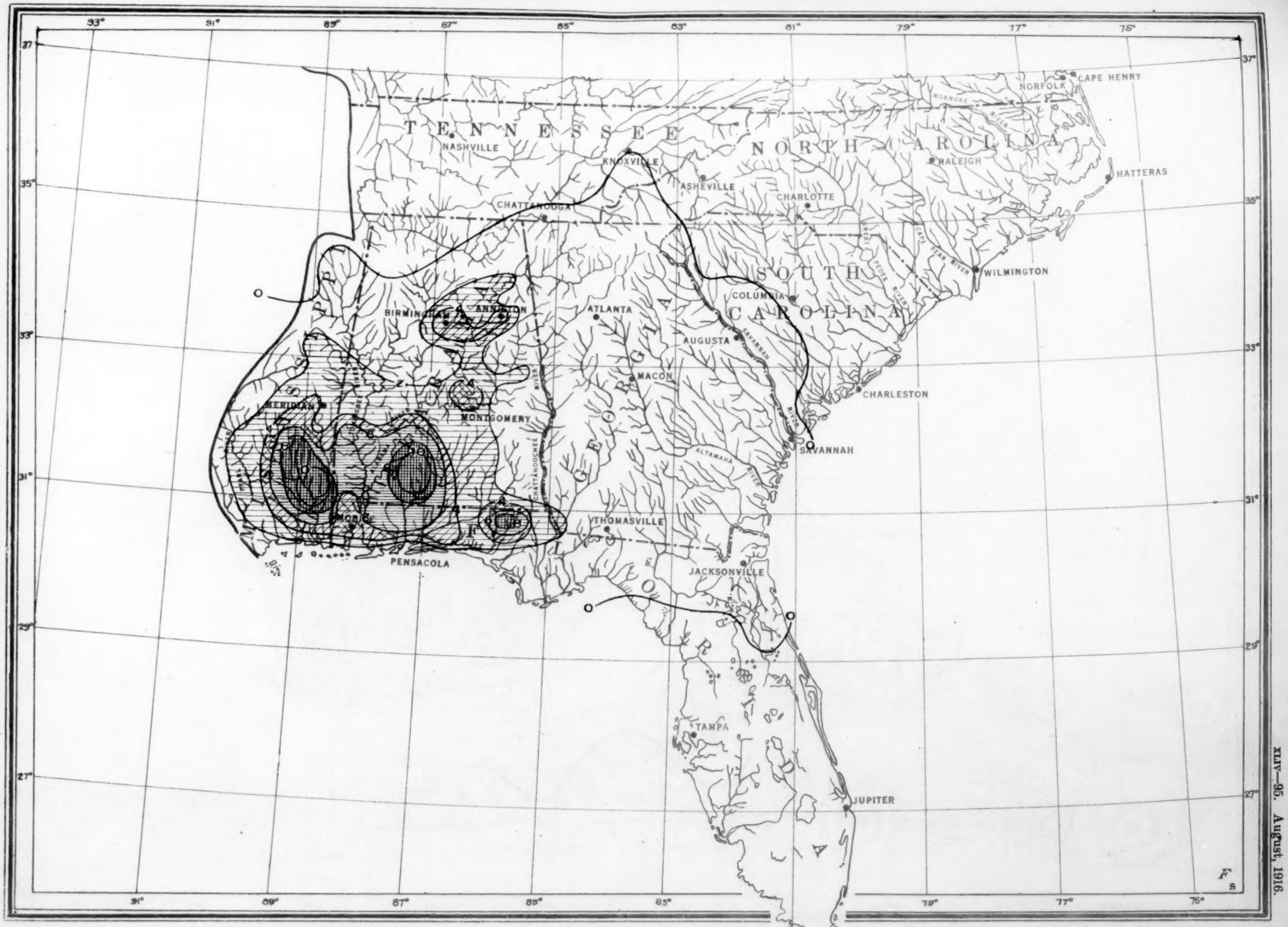




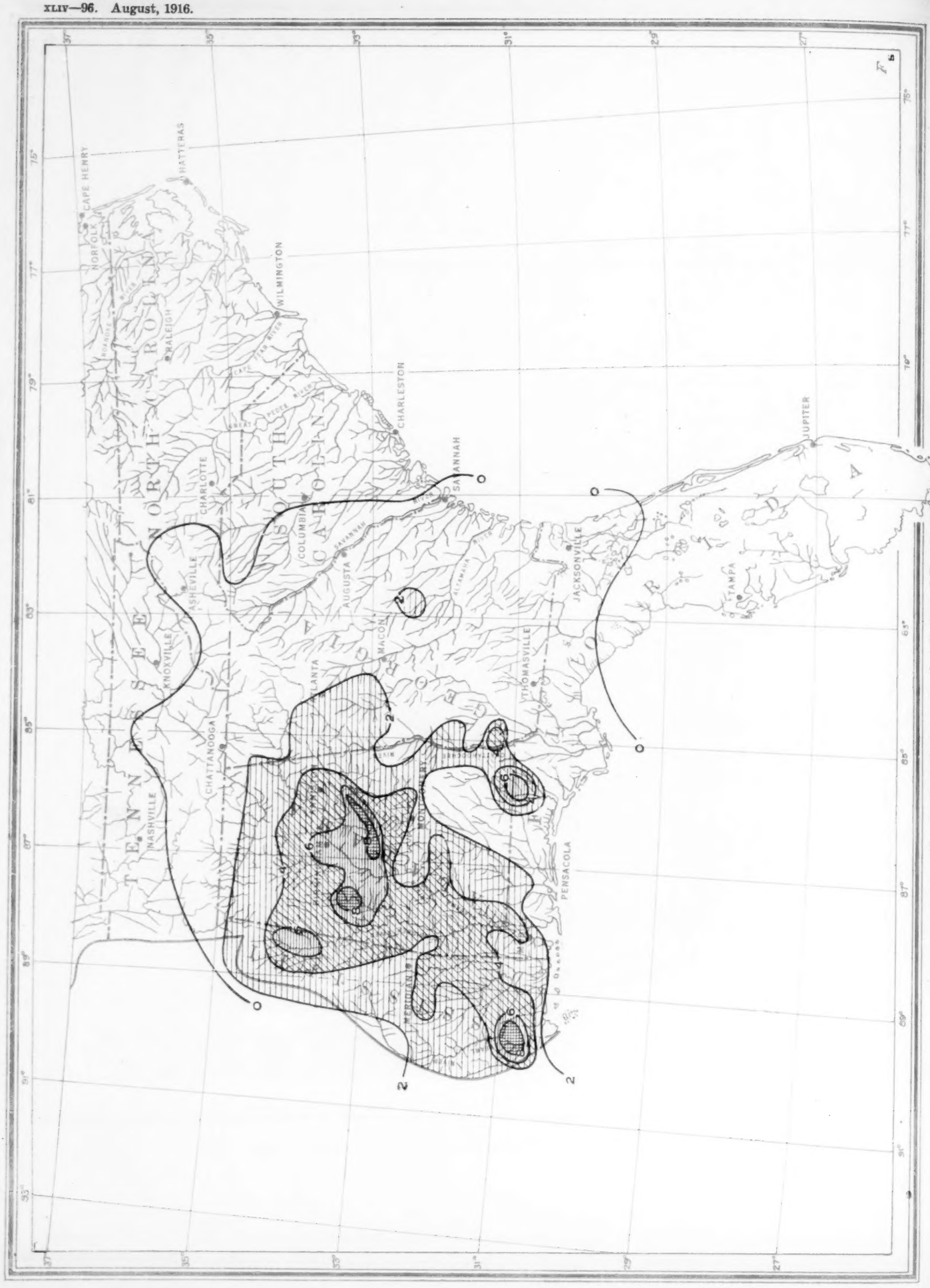
A. J. H. FIG. 1.—Paths of West Indian Hurricanes of July 5 and 13, 1916, and overflow areas along southern rivers.



A. J. H. FIG. 2.—Total Precipitation over southeastern Mississippi, July 5–8, 1916, inclusive.

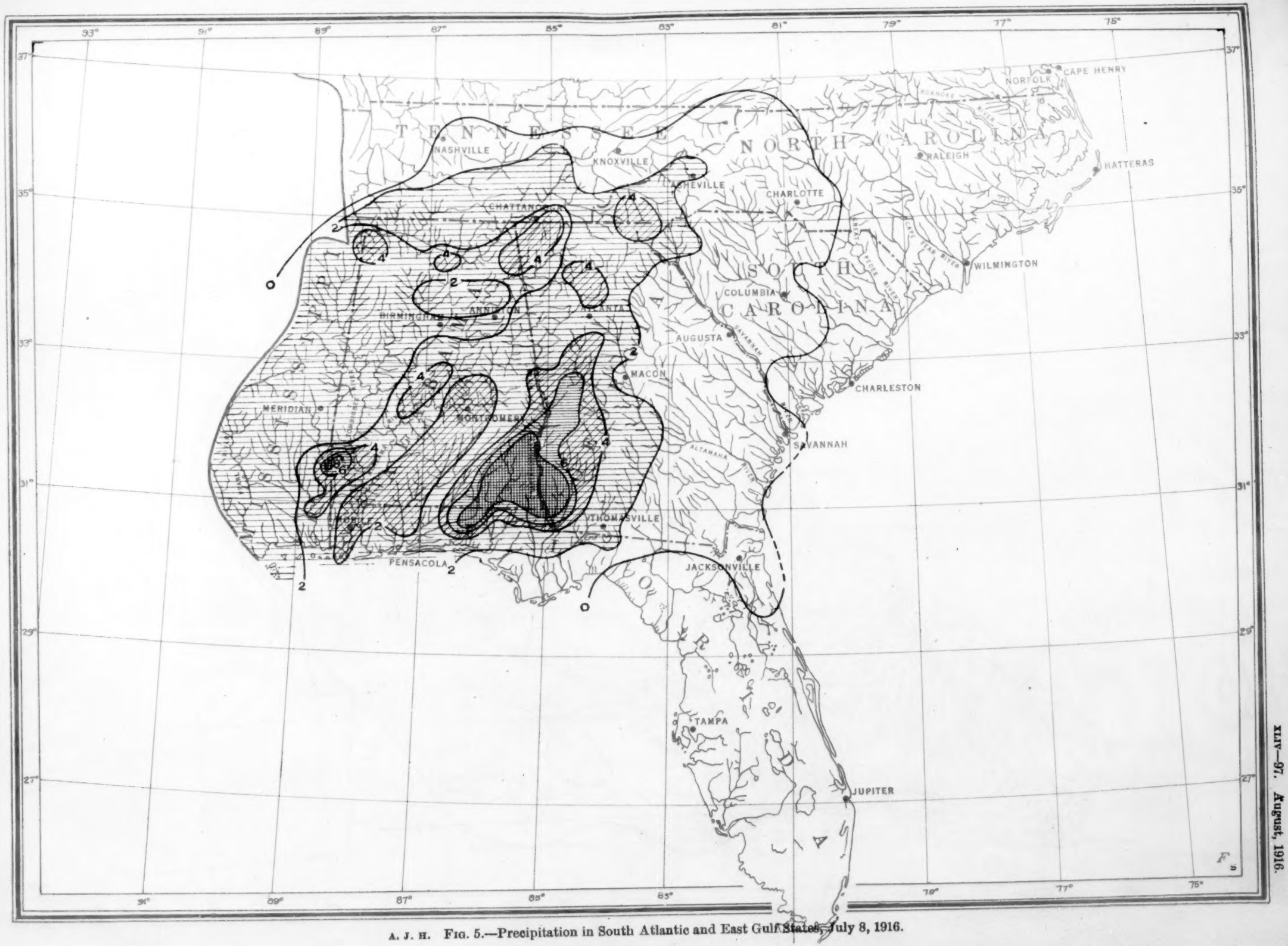


A. J. H. FIG. 3.—Precipitation in South Atlantic and East Gulf States, July 6, 1916.

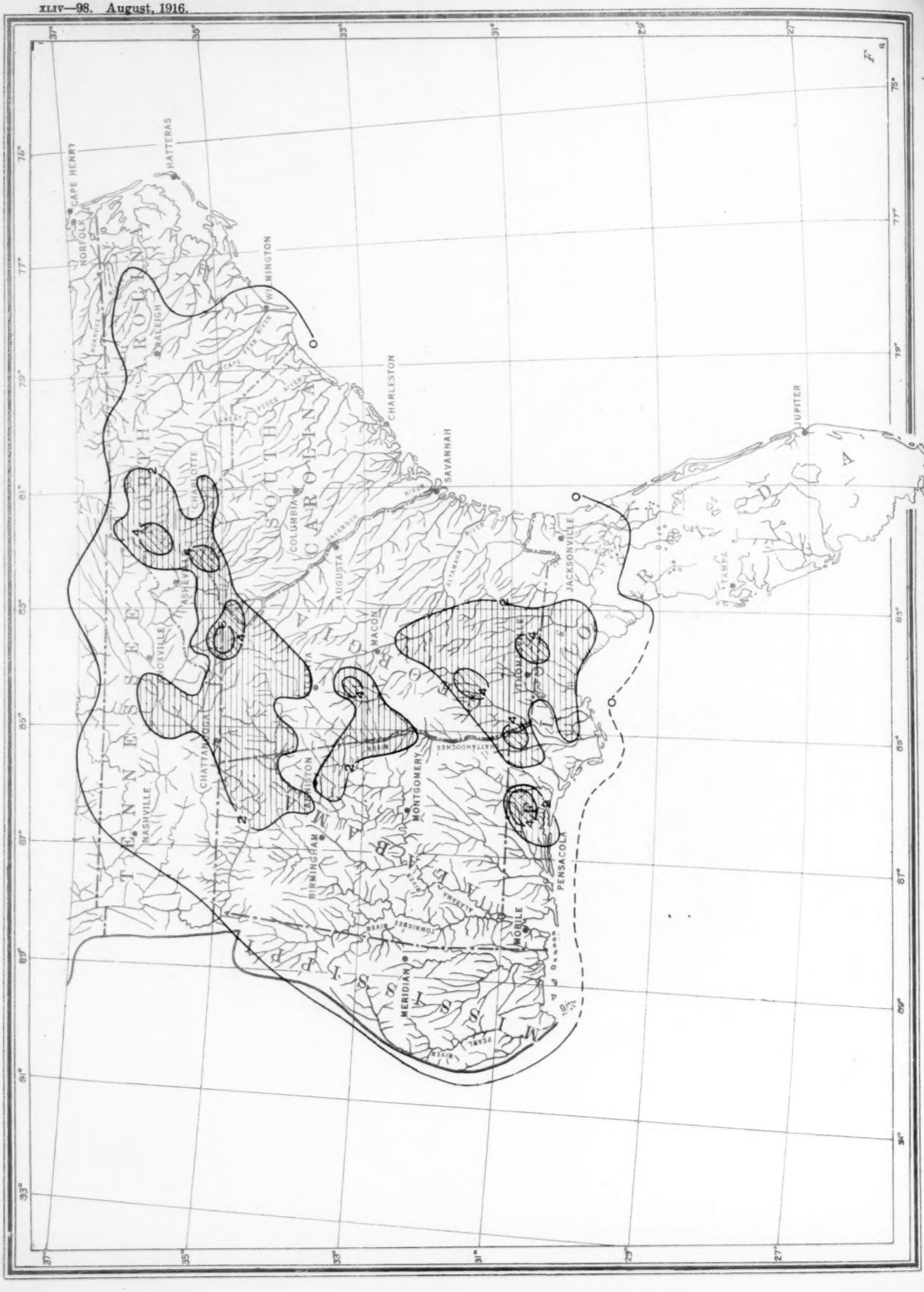


A. J. H. FIG. 4.—Precipitation in South Atlantic and East Gulf States, July 7, 1916.

A. J. H. FIG. 4.—Precipitation in South Atlantic and East Gulf States, July 7, 1916.



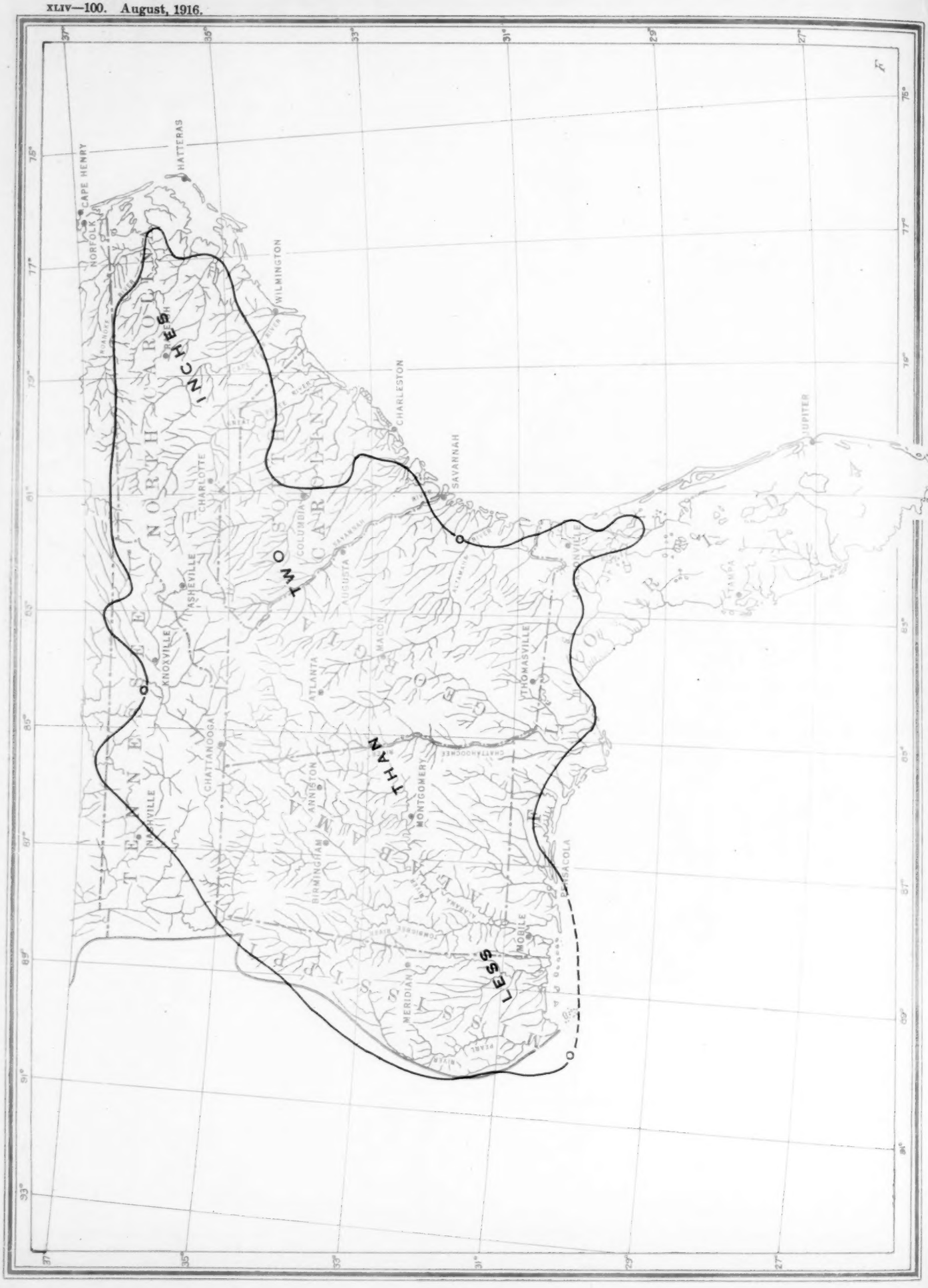
A. J. H. FIG. 5.—Precipitation in South Atlantic and East Gulf States, July 8, 1916.



A. J. H. FIG. 6.—Precipitation in South Atlantic and East Gulf States, July 9, 1916.

A. J. H. FIG. 6.—Precipitation in South Atlantic and East Gulf States, July 9, 1916.

A. J. H. FIG. 7.—Precipitation in South Atlantic and East Gulf States, July 10, 1916.



A. J. H. FIG. 8.—Precipitation in South Atlantic and East Gulf States, July 11, 1916.

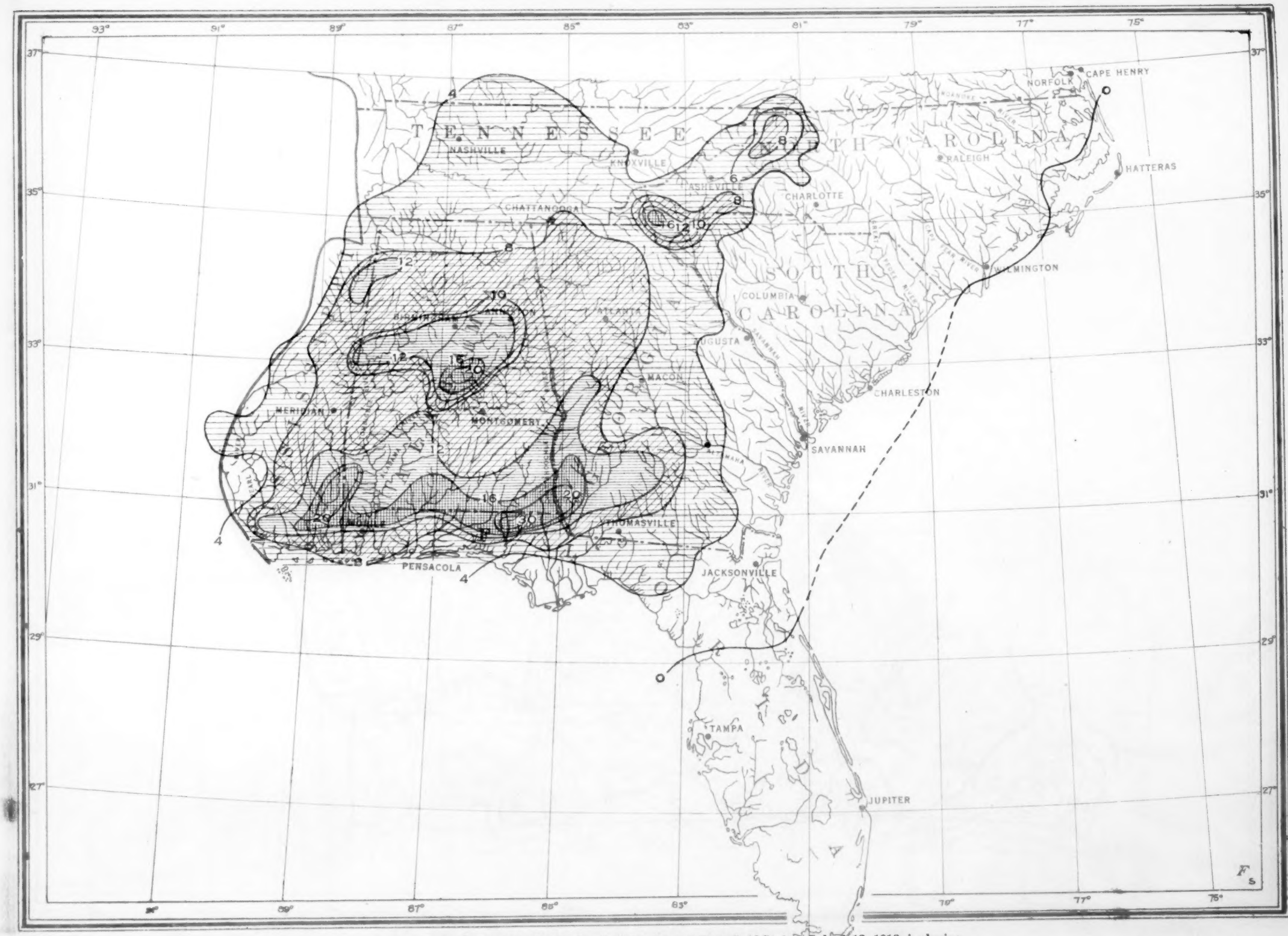
A. J. H. FIG. 8.—Precipitation in South Atlantic and East Gulf States, July 11, 1916.

A. J. H. FIG. 9.—Precipitation in South Atlantic and East Gulf States, July 12, 1916.

FIG. 10.—Precipitation in South Atlantic and East Gulf States, July 13, 1916.

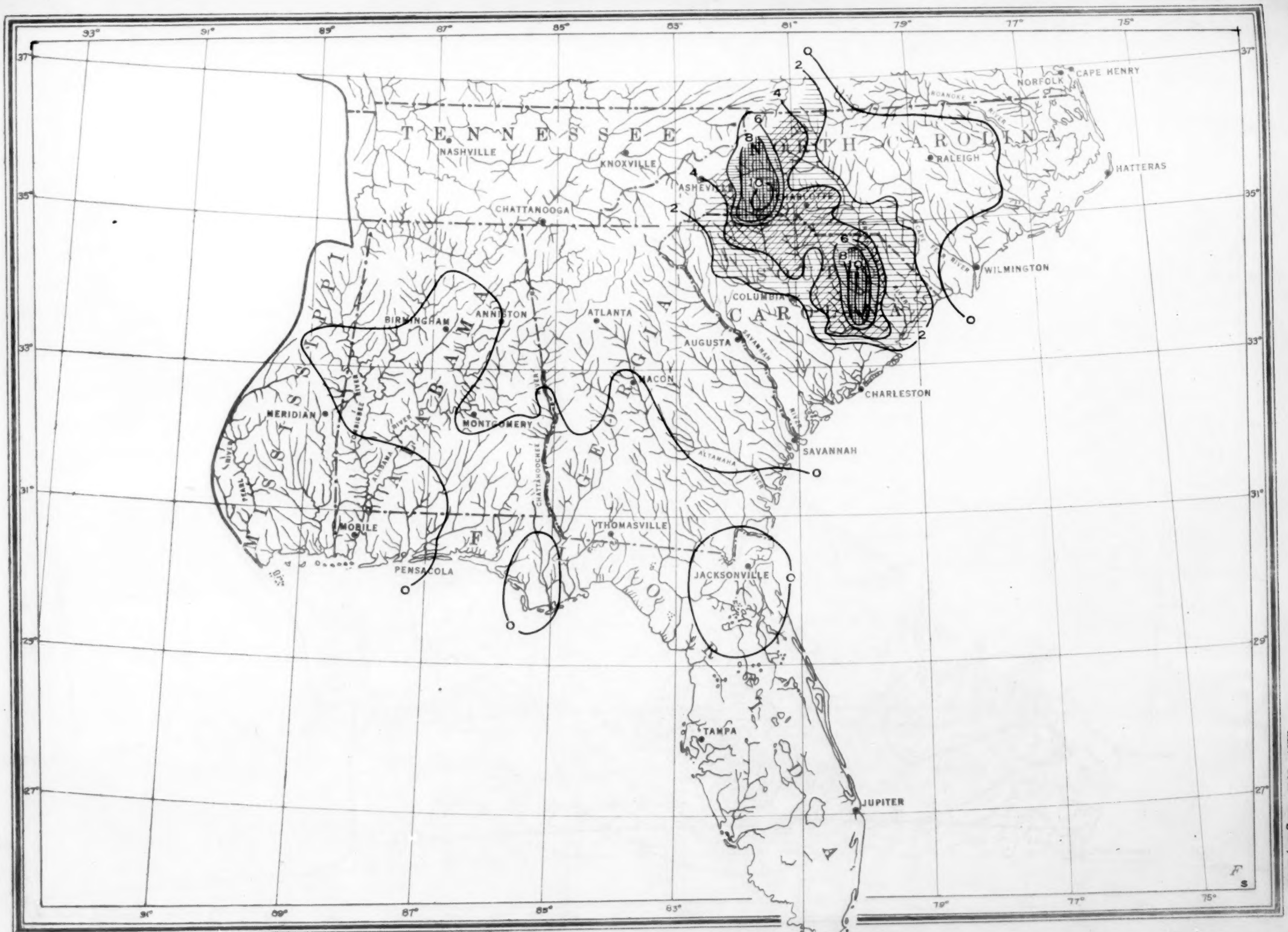
A. J. H.

A. J. H. FIG. 10.—Precipitation in South Atlantic and East Gulf States, July 10, 1916.



A. J. H. FIG. 11.—Precipitation in South Atlantic and East Gulf States, July 6–13, 1916, inclusive.

A. J. H. FIG. 12.—Precipitation in South Atlantic and East Gulf States, July 14, 1916.

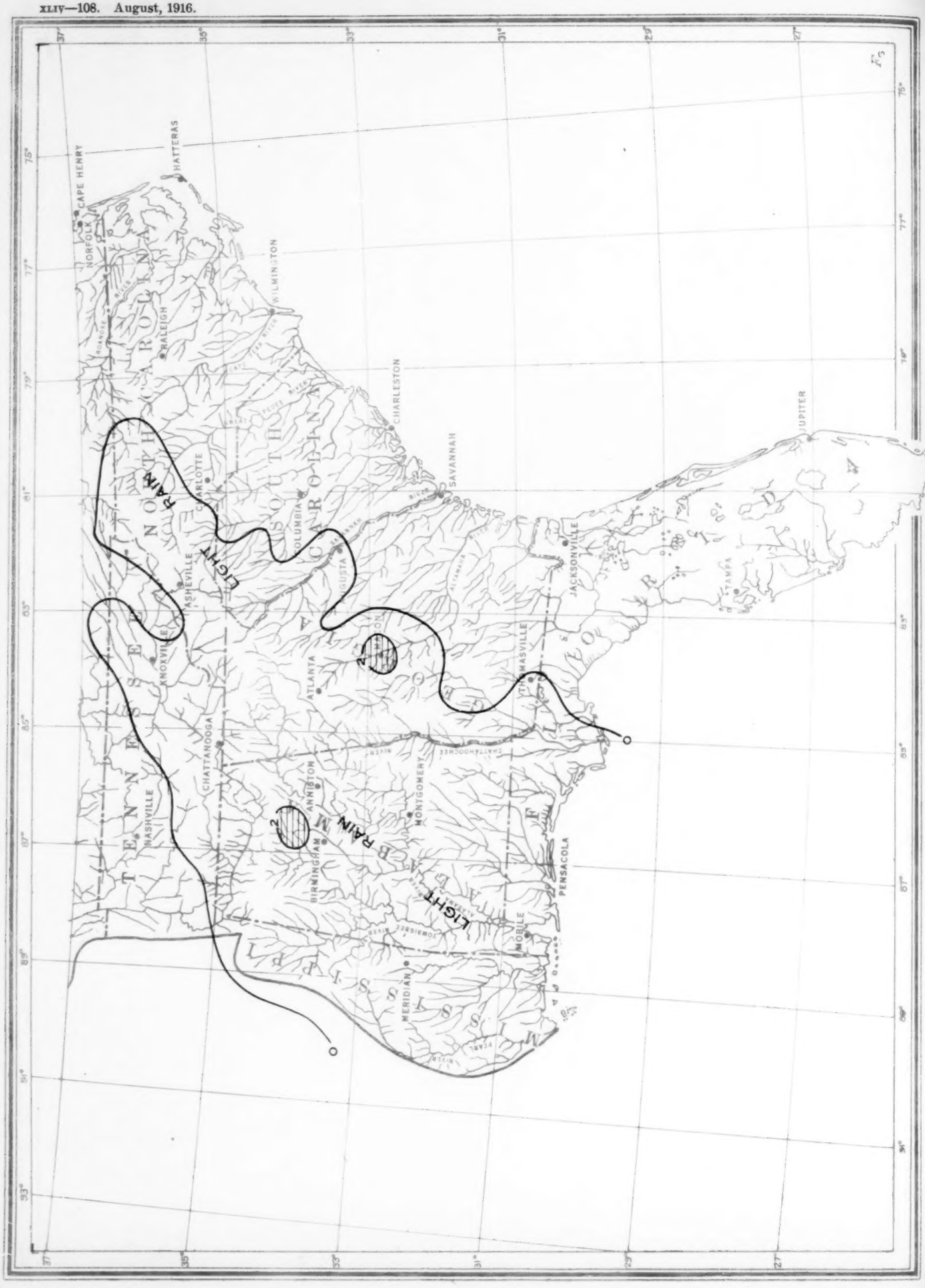


A. J. H. FIG. 13.—Precipitation in South Atlantic and East Gulf States, July 15, 1916.

A. J. H. Fig. 14.—Precipitation in South Atlantic and East Gulf States, July 16, 1916.

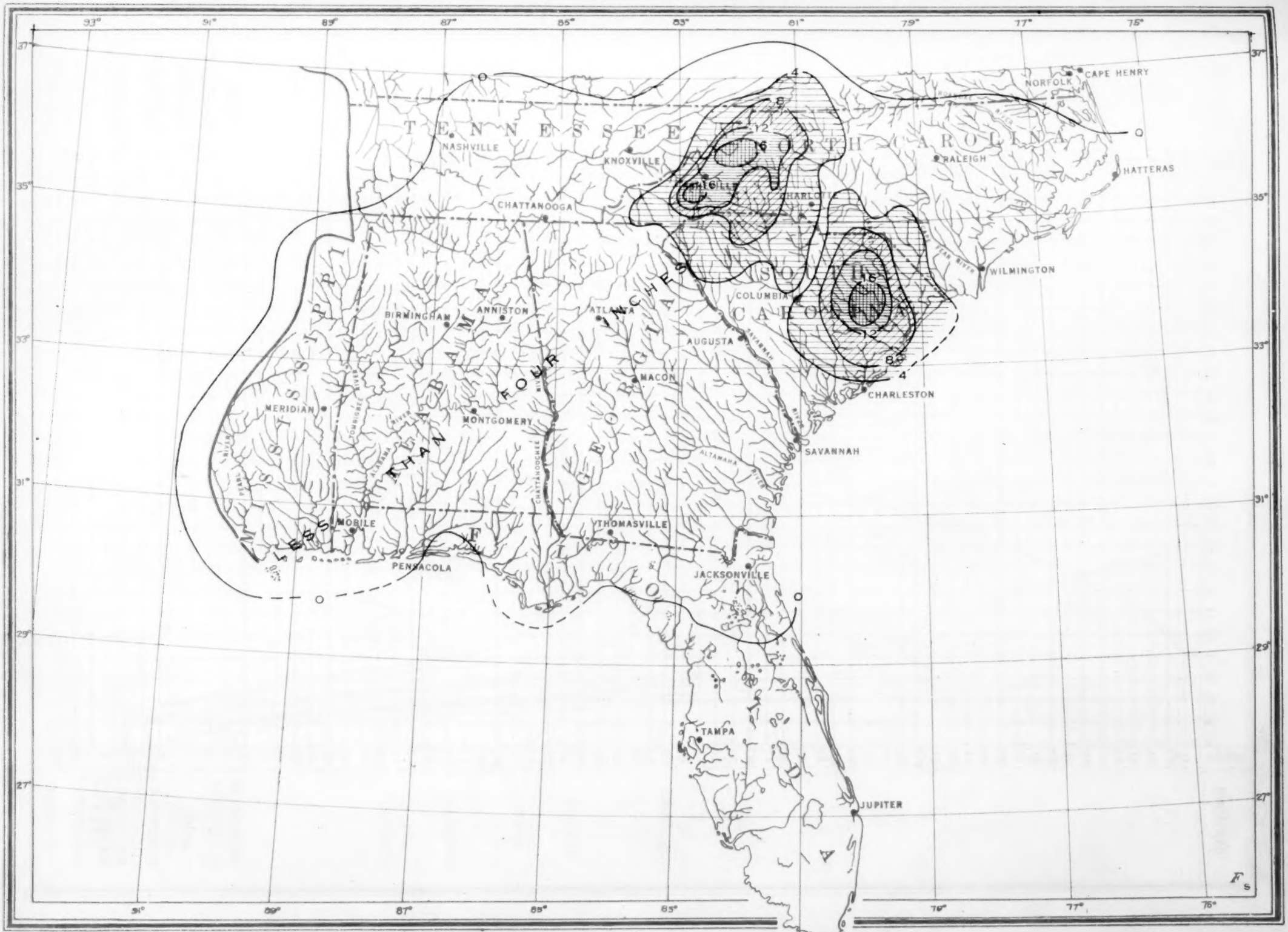
A. J. H. FIG. 14.—Precipitation in South Atlantic and East Gulf States, July 16, 1916.

A. J. H. FIG. 15.—Precipitation in South Atlantic and East Gulf States, July 17, 1916.

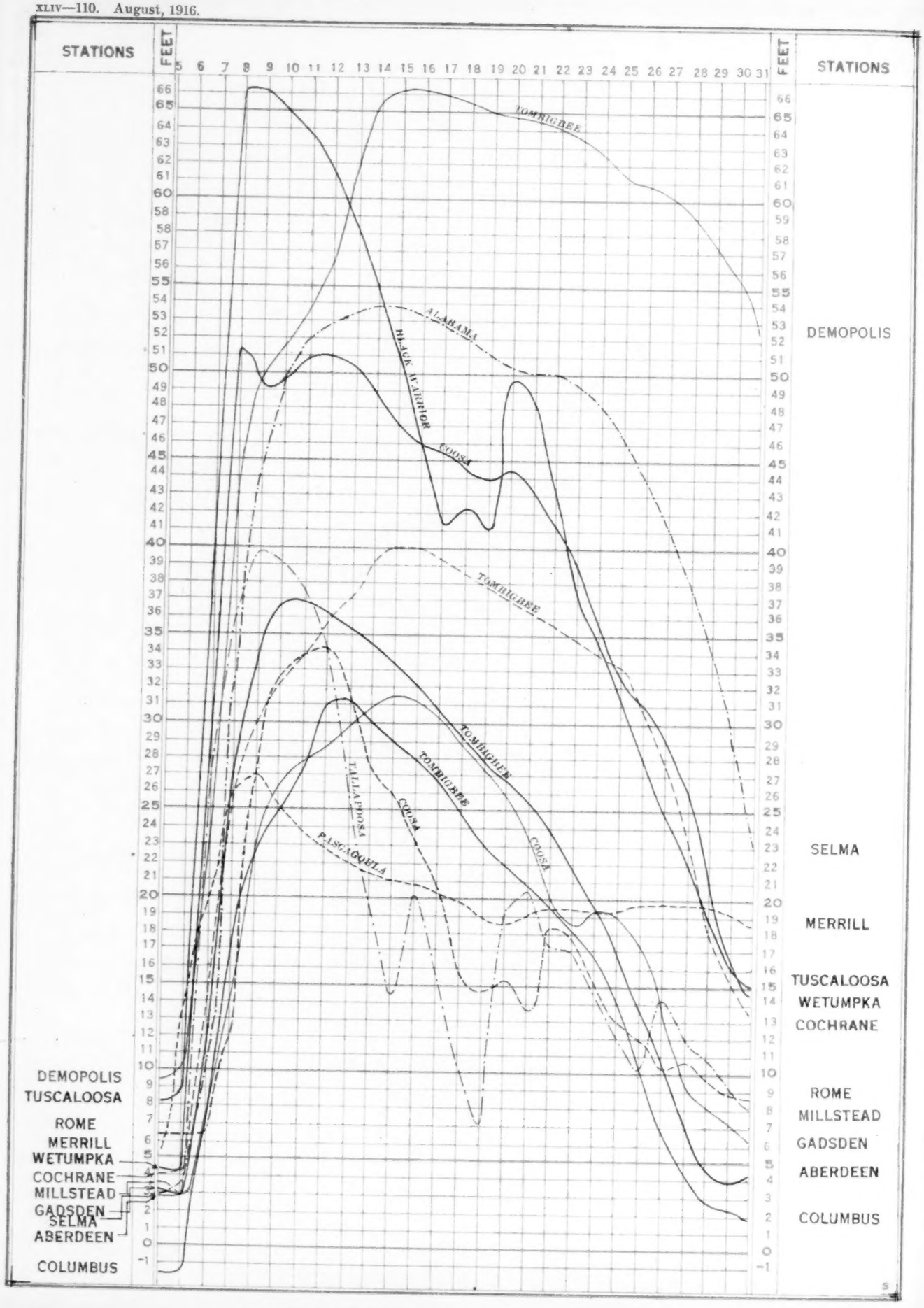


A. J. H. FIG. 16.—Precipitation in South Atlantic and East Gulf States, July 18, 1916.

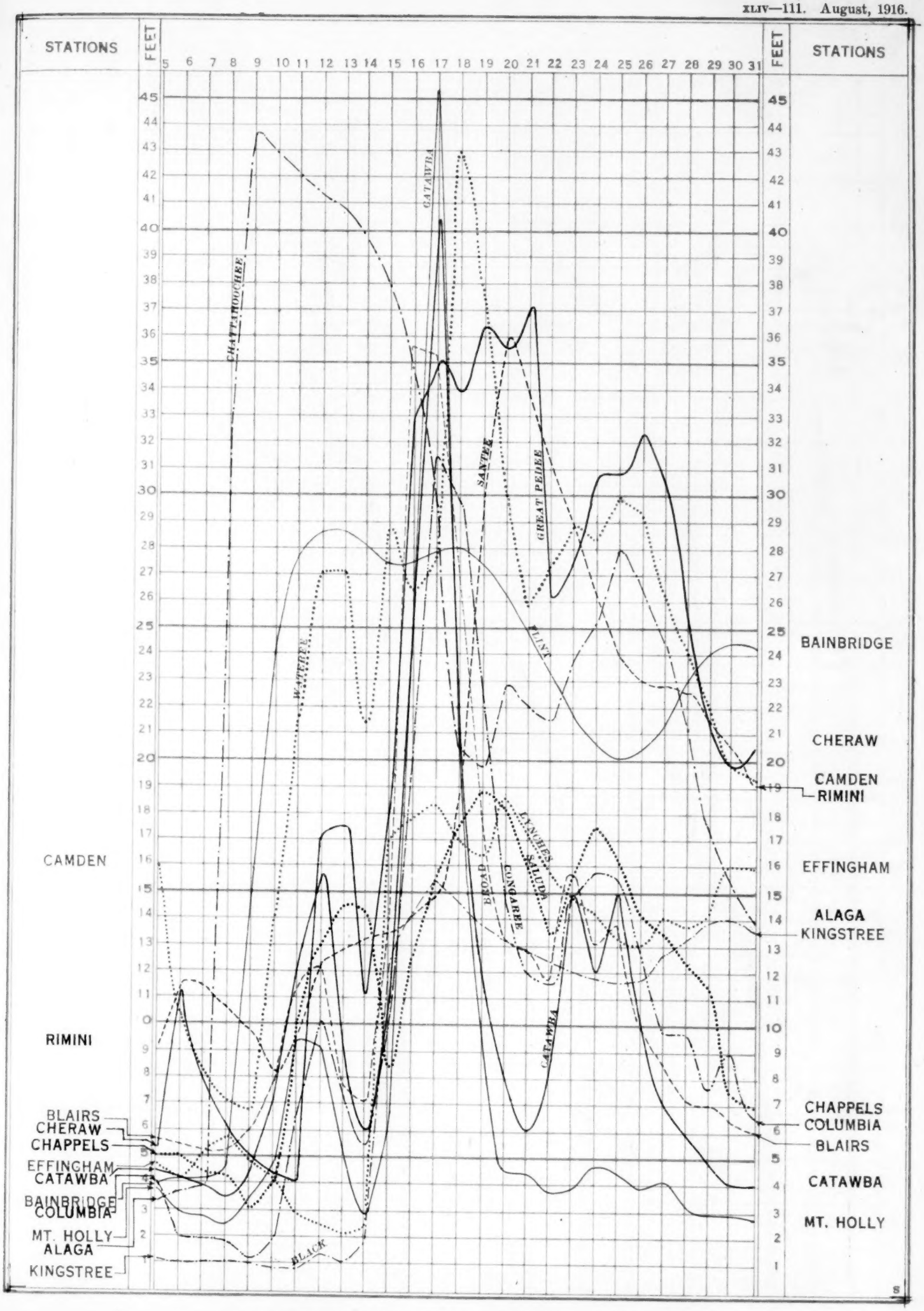
A. J. H. FIG. 16.—Precipitation in South Atlantic and East Gulf States, July 18, 1916.



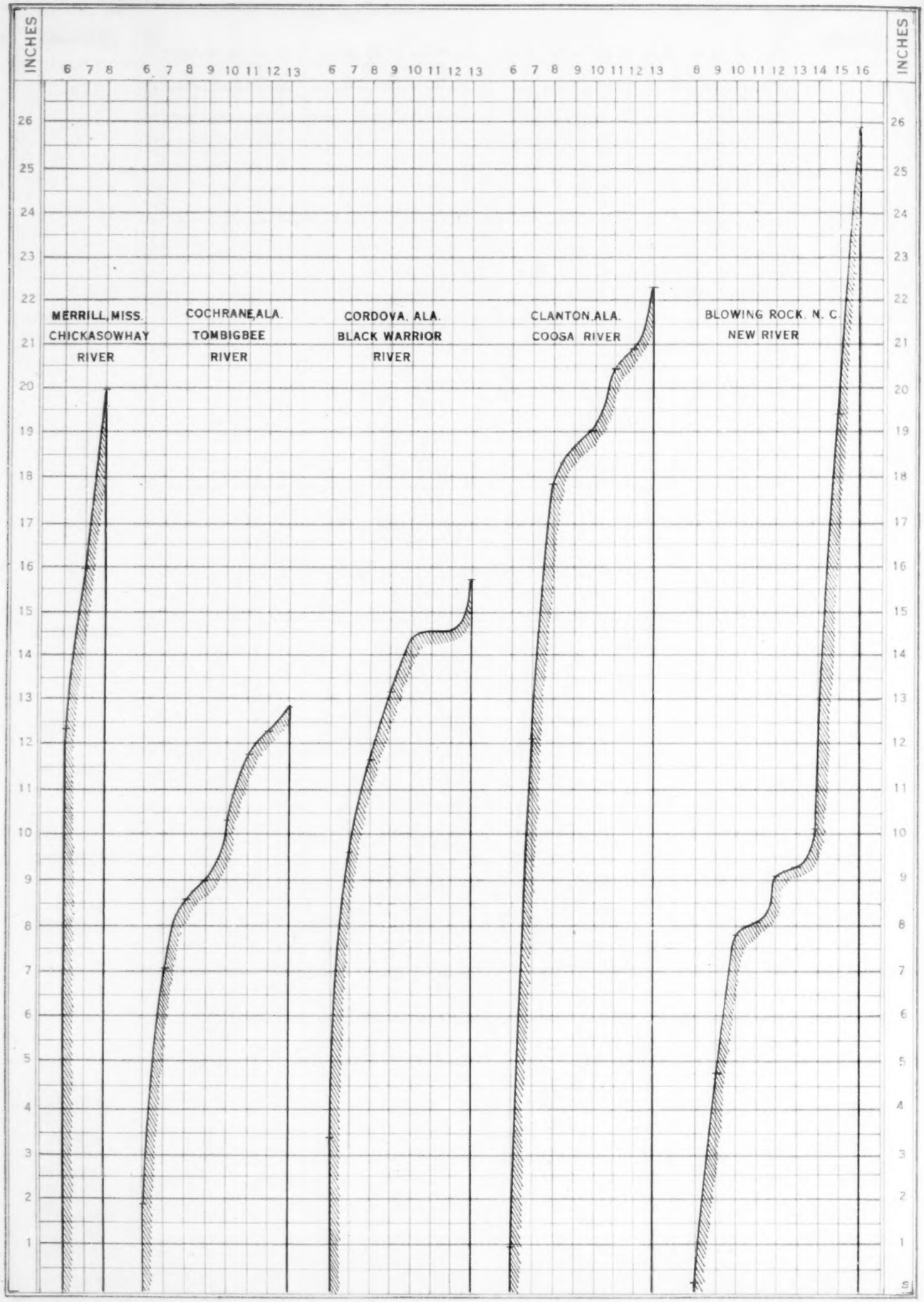
A. J. H. FIG. 17.—Precipitation in South Atlantic and East Gulf States, July 14–18, 1916, inclusive.



A. J. H. FIG. 18.—Hydrographs of some Southern Rivers, July, 1916.



A. J. H. FIG. 19.—Hydrographs of some Southern Rivers, July, 1916.



A. J. H. FIG. 20.—Cumulative precipitation for various dates and localities, July, 1916.